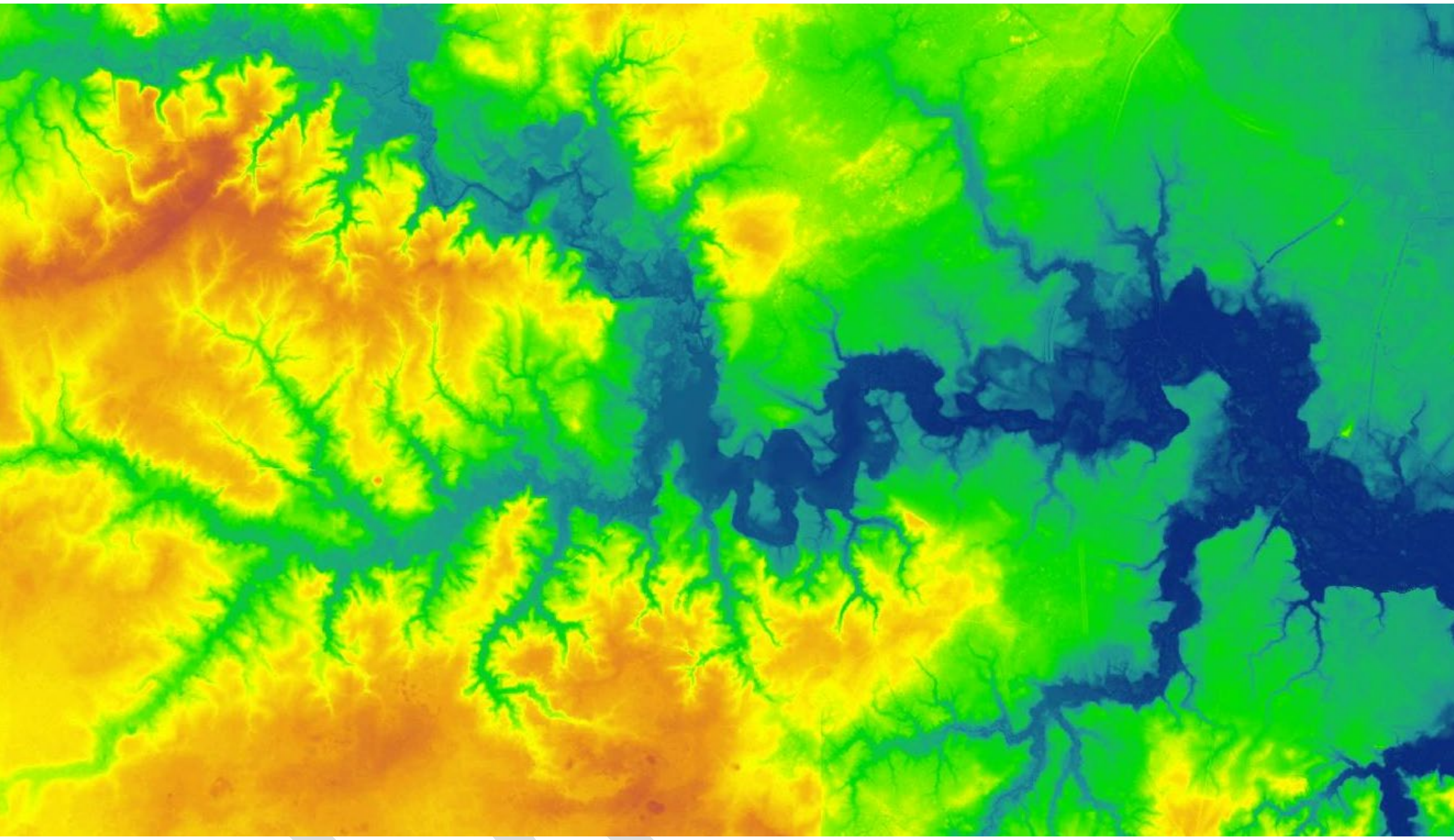
North Carolina Hydrography Working Group



Gap Analysis and

Preliminary Specifications

Presented to:
The Statewide Mapping Advisory Committee
of the
North Carolina Geographic Information Coordinating Council

September 2023

Contents

Acronyms and Data Sources

Data Sources

Much of the text below require some background understanding of the data layers that will form the basis of NC Hydro. The HSSD is a model of water flow; the ATLAS dataset is a subset of the HSSD consisting of modeled intermittent and perennial streams as well as waterbodies greater than 2 acres. NC Hydro will build upon HSSD and ATLAS work and be the public facing NC Hydro dataset for general use.

HSSD: Headwater Stream Spatial Dataset

This is a model of surface water flow represented as preferential flow paths, some of which are labeled as having “at-least” intermittent flow regimes based on a suite of ecoregion based prediction models.

ATLAS: Advancing Transportation Through Linkage and Screening

ATLAS is an NCDOT planning application containing the intermittent and perennial modeled streams from HSSD as well as added attributes from state agencies.

NC Hydro: The proposed updated hydrography dataset which will build upon HSSD and ATLAS data.

NHD: The National Hydrography Dataset

A 24K representation of hydrography maintained by the US Geological Survey.

3DHP: 3D Hydrography Program

A new proposed national hydrography data model that will replace the NHD. This model is based on elevation derived hydrography (EDH).

3DNTM: 3D National Topography Model

To support a broad range of applications, 3DNTM integrates USGS elevation and hydrography datasets to model the Nation's topography in 3 dimensions.

Acronyms

3DEP – 3D Elevation Program

DCA: Data Collaboration Announcement

DWR – North Carolina Division of Water Resources

GICC- Geographic Information Coordinating Council

GIS -Geographic Information Systems

HWG- Hydrography Working Group

NCDCM: NC Division of Coastal Management

NCDEQ – North Carolina Department of Environmental Quality

NCDOT – North Carolina Department of Transportation

NCFMP - NC Floodplain Mapping Program

NCWRC: NC Wildlife Resources Commission

NEPA - National Environmental Policy Act

SMAC -Statewide Mapping Advisory Committee

RDBMS - Relational Database Management System

USACE: US Army Corps of Engineers

USGS – United States Geological Survey

Executive Summary

The North Carolina hydrography dataset represents the water drainage network of North Carolina with features such as rivers, streams, canals, lakes, ponds, and coastline. These data can be used for a wide variety of purposes such as water quality protection and regulation, resource management, infrastructure planning, and cartographic display. The best available hydrography GIS data for the entire State of North Carolina has historically been data based off the 1:24,000 USGS National Hydrography Dataset (NHD). Recently, NCDOT and HSSD created an ATLAS Hydrography Dataset to meet transportation planning requirements. ATLAS Hydrography meets many of the stakeholder's needs by providing a more accurate and consistent representation of hydrography across the state than currently available datasets. Because ATLAS hydrography is now the best available data for the state, the HWG is using the ATLAS Hydrography as a more accurate hydrography dataset that will become NC Hydro. To address requirements for all stakeholders, and to meet the vision of NC Hydro, the HWG has identified needs and gaps between ATLAS data and NC Hydro specifications, discussed in this document.

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Table 1. Summary of issues covered in this document.

The issues identified in this document are not comprehensive, as hydrography data has both cartographic and scientific considerations. The origin of a stream moves through time, as do channels, so representation of continuously evolving features becomes difficult to capture. The HWG has discussed many aspects of the art and science of mapping water features and have reached out to the wider GIS community in multiple ways including outreach meetings, conferences, committee reports, and surveys over the last 12 months to seek feedback on the issues presented in this paper. The goal of the HWG is to make recommendations that meet the needs of the majority of hydrography stakeholders.

Hydrography data projects are ongoing, including updates to HSSD and ATLAS hydrography. National programs including the 3DHP are also evolving. This document represents the recommendations of the HWG based on gaps identified at the date the document was written. Partners are continuously improving datasets, and this document should be used as a guide to understand current issues and needs with the understanding that some issues may be addressed by stakeholders, and new issues may be identified. The following report will outline generalized schemas and attributes as well as recommendations for major issues.

Introduction

Historically, the best available hydrographic GIS data available for the entire State of North Carolina has been data based off the 1:24,000-scale (24K) NHD. The state and USGS worked closely together to create the NHD dataset between 1984 and 2005. In 2006, the NC Department of Environmental Quality (NCDEQ) released on NC One Map statewide 24k hydrography with additional attributes relevant to the program needs of the DEQ such as official state assessment unit names. In 2007, 19 counties in the western portion of the state that were impacted by Hurricanes Frances and Ivan received hydrography data derived from Light Detection and Ranging (lidar) data as part of the Hurricane Recovery Act of 2005. For the remaining 81 counties in the state, the best dataset available is based on 1:24,000 hydrography as mapped from USGS Topographic maps of varying ages, most decades old.

Mapping of hydrography has advanced since the creation of the legacy 1:24,000 NHD and the lidar derived hydrography created in 2007. Higher quality base data combined with more advanced data extraction techniques now produce more accurate hydrographic feature production.

The primary contributors to hydrography data in North Carolina are the Department of Environmental Quality Division of Water Resources (DEQ-DWR), North Carolina Department of Transportation (NCDOT) and the North Carolina Floodplain Mapping Program (NCFMP). Each found that the current 24K hydrography did not meet their needs. NCDEQ created the Headwater Streams Spatial Dataset (HSSD), a lidar-derived hydrographic dataset that is primarily a hydrographic model and includes representations of water flow beyond the on the ground stream network. Modeled streams most likely to be intermittent or perennial will be used in NCDOT's planning tool, Advancing Transportation through Linkages, Automation, and Screening (ATLAS). ATLAS is a project screening tool used by NCDOT that combines hundreds of data layers to facilitate transportation planning. The ATLAS hydrography meets many of DOT's needs, but as it was designed specifically to meet transportation planning needs within the NCDOT ATLAS platform, it includes some NCDOT-specific needs while it may not meet all the needs of the broader GIS community. NCFMP produces hydrography data including hydrography breaklines for waterbodies as part of their flood modeling process.

As the HSSD and ATLAS groups were generating and processing the ATLAS hydrography, the USGS launched the 3D Hydrography Program for The Nation (3DHP) which will integrate the creation of hydrography with elevation held within the 3D Elevation Program (3DEP), the USGS's nationwide program for elevation data collection. USGS created standards for Elevation-Derived Hydrography (EDH) which uses many of the same data extraction techniques as HSSD. The goal is to replace the hydrography in NHD with the more accurate hydrography derived from EDH. USGS is currently piloting hydrography creation projects in small, selective areas across the nation.

Every two years, the National States Geographic Information Council (NSGIC) performs a Geospatial Maturity Assessment (GMA), a national review of statewide foundational datasets resulting in scores that allow states to assess progress toward mature, accurately maintained data. In 2021, North Carolina scored high on the GMA scorecard overall (A-), but the hydrography scored only a C+ because of the inadequacies of our hydrography, lack of maintenance funding, and lack of a stewardship agreement with the USGS.

The vision of the Hydrography Working Group (HWG) is of a state-maintained, integrated hydrographic model that can be used by all stakeholders from local to federal.

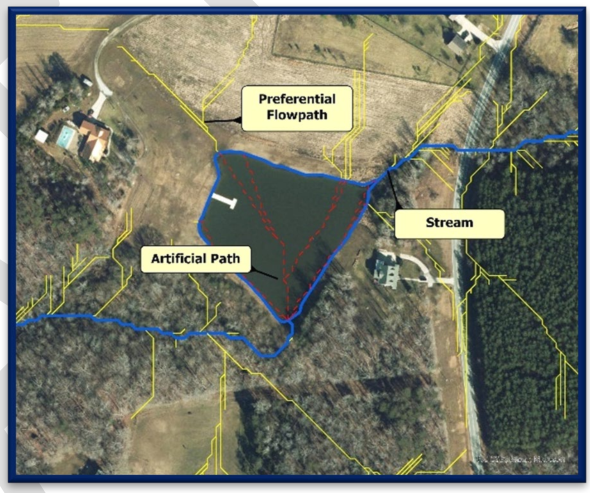
Statement of Need

The Hydrography Working Group (HWG) was formed because the best available hydrography for the state was not meeting the GIS user community's needs. The NC Hydrography (NC Hydro) dataset can be created by consuming the base linework of the ATLAS project and integrating anticipated elements of the USGS 3DHP. NC Hydro must meet the business needs of the majority of stakeholders including geometric accuracy, completeness, and attribution.

Existing North Carolina Hydrography Data Status

Data Feature Types

Text in this document refers to many features included in hydrography data. Keep in mind the following feature type definitions as you read the text.



Preferential flow path: A modeled depiction of where water flows across the surface of the earth. These paths may not be streams. They may simply be places where water flows toward a stream or waterbody.

Stream: An intermittent or perennial stream

Drainageway: Delineated flow paths where terrain modelling indicates potential headwater drainage, but no channel is detectable.

Artificial Path: A connector line through a waterbody that maintains connectivity with stream network lines.

Modeled Connector: a line connecting network features based on a preferential flow path from the HSSD model. These connectors may not exist on the ground.

Waterbody/2D Waterbody: A body of water such as a pond, lake, reservoir, or wide river that is represented as a two-dimensional polygon feature.

Double line stream: A large river wide enough to be represented as a waterbody rather than a line.

Reach Points: Data points created during the HSSD creation process. They can be either a starting point or endpoint of a flow path.

HSSD

The Headwater Streams Spatial Dataset (HSSD), created by NCDEQ, is the source data used to generate hydrography data for the NCDOT ATLAS project and is funded in part by the NCDOT. The HSSD creates a predictive model of where water flows across the earth's surface. These data are currently generated from Digital Elevation Model (DEM) surfaces generated from Quality Level 1 and 2 (QL1 or QL2) lidar. Reach points are generated from 10-foot DEM surfaces and identify paths initiated by a geomorphic threshold that begin well above the point at which a stream would be expected. Flow paths are generated from and between reach points. There is a unique identification number assigned to reach points (and later added to the flow paths between the reach points) linking cell-level data from DEM surfaces and models. There are no open water features such as lakes, streams and ponds or polygonal features.

HSSD data has been generated statewide, and the data can be updated when new base data becomes available.

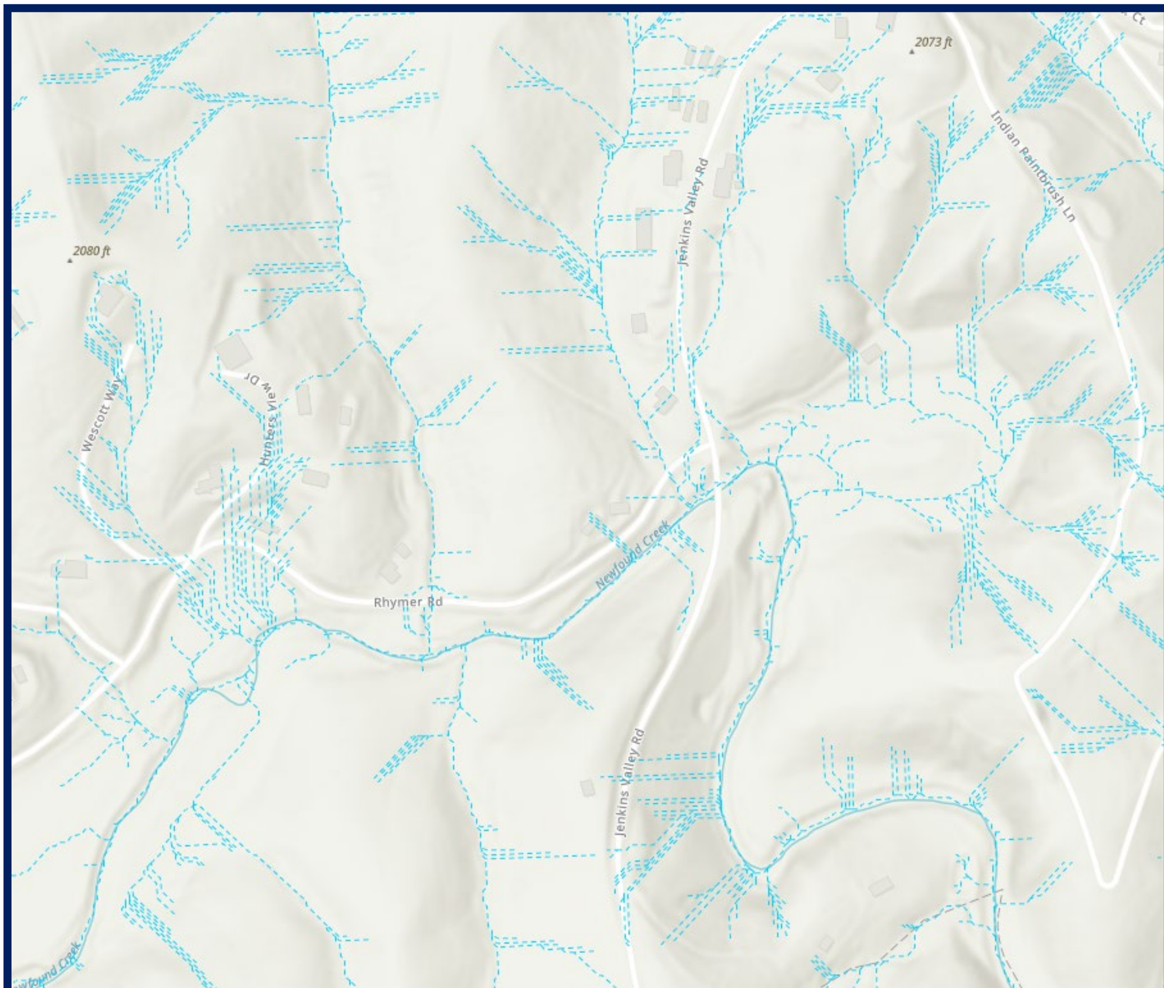


Figure 1. HSSD dataset models preferential flow paths upstream of the labeled intermittent/perennial streams

ATLAS Project

The NCDOT ATLAS Project was begun in 2017 specifically to streamline project planning and natural resource agency collaboration. Prior to this, the NCDOT funded and collaborated with the HSSD for some time and continues to do so. Predictive modeling was developed for specific applications within the Kinston Bypass GIS Pilot Project. The predictive stream models, along with complimentary wetland predictive models, were used in lieu of detailed field data collection to streamline project delivery and reduce costs. Due to the success of the GIS Pilot Project, expanding those efforts to a statewide layer was a critical part of the ATLAS project. The ATLAS Hydrography Dataset (ATLAS Hydro) was developed to improve stream location information to facilitate comparisons of transportation project alternatives in the early stages of project planning, and to quantify the amounts and attributes of possible streams that may be impacted during construction for early and accurate forecasting of project needs and budgets. The ATLAS Hydro provides detailed information about the location and attributes of potential streams for NCDOT reporting and permitting. These attribute needs were informed initially by Natural Resource Technical Report requirements produced by the NCDOT as part of NEPA documentation.

The ATLAS Hydro, version 1 (v1, 2019) was developed using hydrography linework developed by the HSSD program using 20-foot resolution DEMs built from legacy (2007) lidar bare earth points from the NC Floodplain Mapping Program (NCFMP) and the outlines of waterbodies generated by the NCFMP from QL2 or better lidar captured from 2014 to 2018. These data depict potential streams identified by HSSD models as "at-least" intermittent. After discussions with agencies including the NCDEQ, NC Division of Coastal Management (NCDCM), NC Wildlife Resources Commission (NCWRC), and US Army Corps of Engineers (USACE), additional data used in NCDOT planning and permitting were appended to these data as attribute classes, including agency jurisdictions, trout waters, anadromous fish waters, and temperature classifications. The ATLAS Hydro v1 data were designed to be queried manually as well as automatically by the ATLAS Screening Tool, and some aspects of the ATLAS Hydro schema were designed to ensure data quality and improve understanding during automated queries (such as the identification of unique identifiers for unnamed tributaries in versions 1.1 through 1.4).

The geometry for the ATLAS Hydro, version 2 (v2, 2022) dataset was generated by the HSSD program using 10-foot resolution DEMs created from the QL2 or better lidar data. The ATLAS Hydro, v2 dataset was designed specifically to work with advancements in the Project ATLAS platform and improve data quality and management. Specifically, the schema was updated from a 'flat' feature class to a Relational Database Management System (RDBMS), in which unique identifiers for each feature are matched with data tables that can be maintained and updated separately from the ATLAS Hydro geometry. These relational tables provide a method for adding and updating information without affecting spatial information. This update also matches the structure of the existing NCDEQ RDBMS to improve data updates and data movement. Additional attributes that are used by the NCDOT in specific project situations, or potentially useful information generated during production (some NCDEQ attributes and the underlying HSSD data) were maintained.

The NCDOT and HSSD intend to continue to update the ATLAS Hydro to refine stream geometries and extents where necessary. The NCDOT intends to continue updates to hydrography resources through continued collaboration with the HSSD to continually refine the capabilities of broad and accurate planning tools and the identification of permitting needs.

ATLAS Schema

ATLAS hydrography data is based on polyline features. Those features contain the following attributes.

ATLAS_Hydrography_v2 feature table			
Field Name	**Data Type**	**Definition and Table Connections**	**Examples**
HYDROID	Text	Unique ID for each segment and key to the following tables: • Anadromous Fish Spawning Areas • Cold, Cool, Warm Habitat Temperatures, • Descriptive Boundaries of Coastal, Joint, and Inland Waters, • Eastern Brook Trout Joint Venture Trout Waters, • Flow regime –Identifies at least intermittent streams	UPNUS_220302_506851
AUID	Long	ID for NCDEQ Assessment Unit streams that are Mainstems. Also provides a link back to many of the NCDEQ business tables: • NCDEQ Water Quality Assessments • NCDEQ Assessment Unit Information • NCDEQ Assessment Unit Ratings (WRAPS) • Impairment status (303(d))	8400
HUC10AIDX	Text	Key to the following table • HSSD Reach Point Data table	UPNUS01_144572155
HYDROTYPE	Text	Hydro type features domain.	Domain Value
FEATURETYPE	Text	Drainage feature types with domain.	Domain Value
IMPACT	Text	NCDOT ATLAS-specific impact assessment	Yes or No
AUNAME	Text	State name for Assessment Unit.	Weaver Creek
INSTATE	Text	Is feature in North Carolina.	Yes or No
AUIDA	Text	ID for All NCDEQ Assessment Units that are Tributaries. Also provides a link back to many of the NCDEQ business tables (excludes impairment): • NCDEQ Water Quality Assessments • NCDEQ Assessment Unit Information • NCDEQ Assessment Unit Ratings (WRAPS)	8401

FEATURETYPE and HYDROTYPE attributes are assigned within the ATLAS Hydro. Features without AUID numbers that are identified as at least intermittent are labeled as Unnamed Tributaries (UTs) to NCDEQtracked stream Assessment Units (AUs). Each UT is identified with a unique identification number and the waters to which it drains (i.e., UT 397 to Neuse River). Features that are identified with a flow regime less than intermittent are labeled as drainage ways and assigned a non-unique name that reflects the waters to which it drains (i.e., UT to Neuse River).

ATLAS FEATURETYPE Domain		
Code	**Description**	**Definition**
1	MAINSTEM	NCDEQ Assessment Units
2	TRIBUTARY	Tributaries to Mainstems
3	ARTIFICIAL PATH	Artificial Paths through waterbodies
4	DRAINAGE WAY	Less than intermittent flow.

Table 2. Atlas feature types used to attribute stream and waterbodies to describe place in network.

As a rule, Lake/ponds smaller than 2+ acres and double bank streams smaller than 100 feet across are not collected. These data were derived from waterbodies collected by NC Division of Emergency Management (NC EM). In the sample dataset, there are some features that are smaller but not many.

ATLAS HYDROTYPE Domain	
Code	**Description**
1	Stream/River - Single
2	Stream/River - Double
3	Lake/Pond
4	Atlantic Ocean

Table 3 Atlas Hydrotypes used to attribute stream and waterbodies to differentiate types of features

An Assessment ID (AUID) is assigned to stream features linking NCDEQ data to Assessment Unit streams (AUs) and appropriate flow paths are assigned. The AUID is also the link back to the NCDEQ business tables. The following table summarizes the attributes and the tables the attributes are linked in ATLAS Hydrography.

ATLAS Hydrography v2 Data Schema

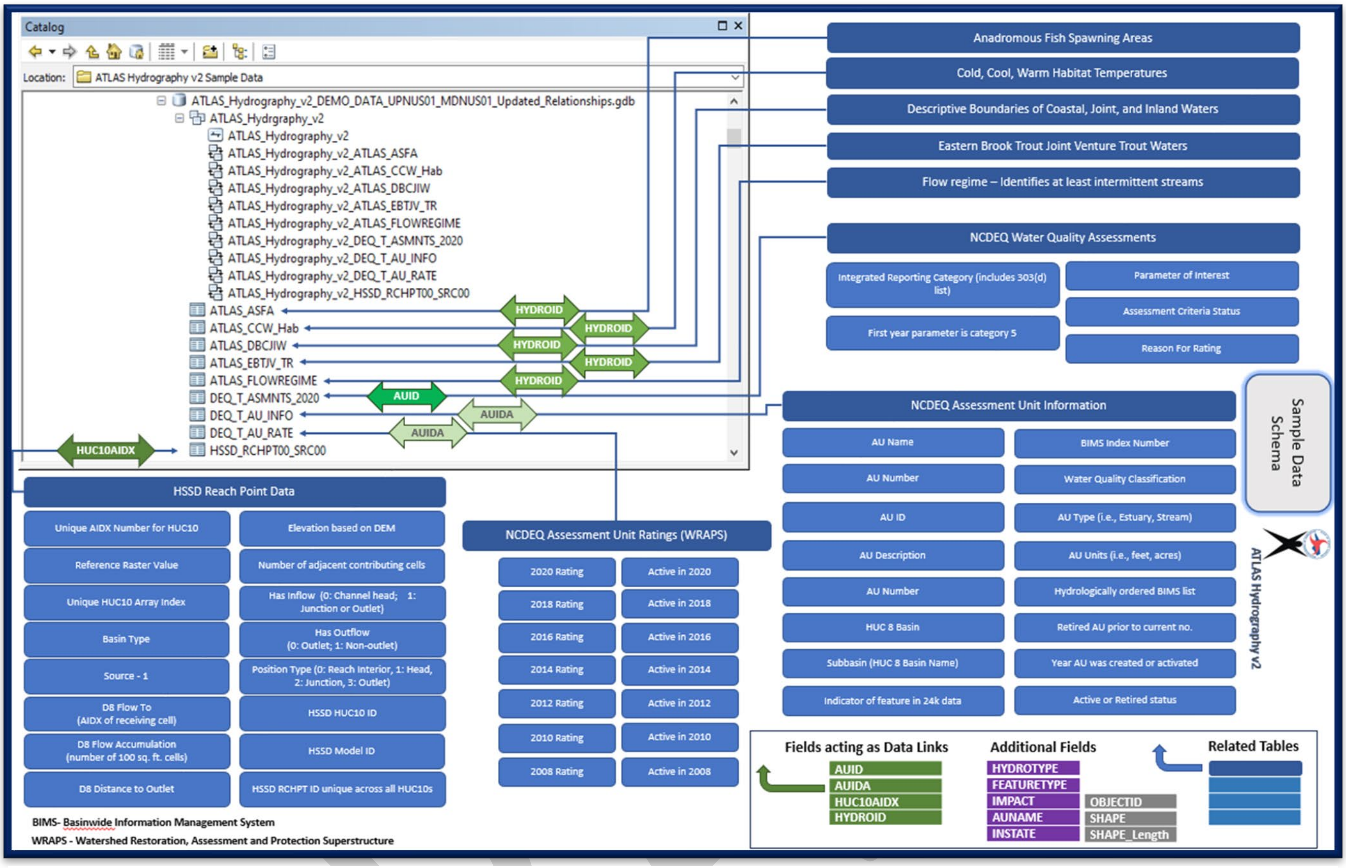


Table 4. ATLAS schema showing relationships between geometry and related state data tables

3DHP -Elevation Derived Hydrography (EDH)

As part of the 3D National Terrain Model (3DNTM,), an effort is underway to improve the positional quality of the USGS NHD to be more closely aligned with the 1-meter 3DEP DEMs. The 3DNTM is a new initiative to update and integrate the USGS elevation (3DEP) and hydrography data (3DHP). The improved integration of elevation and hydrography is an integral part of the future vision of The National Map. The 3DHP will collect hydrography data to meet the following specification documents: Elevation-Derived Hydrography Acquisition Specifications and Representation, Extraction, Attribution, and Delineation *(READ Rules).* The goal of the specification is to integrate the hydrographic features vertically and horizontally with the 3DEP lidar-elevation products. Meeting the specifications will result in elevation-derived hydrograph (EDH) appropriate for hydro flattening and hydro enforcement and serve as the input hydrography source to the 3DHP data model.

The 3DHP is in a period of growth and planning. At the time this report was written, there is no national EDH dataset. The USGS is contracting with Federal and State agencies to collect EDH in basins throughout the U.S. to assess best practices and test methodologies. The USGS plans to transfer existing NHD data to the 3DHP dataset to temporarily fill the dataset until EDH data is produced to replace it. Program funding is available through the Data Collaboration Announcement (DCA), a process for finding and selecting partnerships to fund acquisition of 3DEP and 3DHP data. Contributors to EDH must meet the EDH specifications, but interim data might be accepted if it meets some baseline requirements. The USGS is still evaluating the review and acceptance process for elevation derived data produced outside the 3DHP contracting mechanism.

The following table lists some key points of EDH applicable to NC Hydro for future integration. This table does not contain an exhaustive list of all EDH specifications. Refer to the READ rules and acquisition specifications above.

Key points of EDH applicable to NC Hydro for future integration

Data Source
1-m 3DEP DEMs
Hydro flattening breakline feature collection for features greater than 2 Ac.
Geometry /Topology
Each feature type must be z-enabled, with z-values assigned to each point, vertex, and node. The feature classes (pointZ, polylineZ, and polygonZ) are 3D geometry.
All flow lines must be connected at nodes, without gaps, crossed lines, or overshoots
All single line flow lines and double line stream features maintain downstream monotonicity.
Minimum waterbody size of .25ac
Lake/ponds and reservoir waterbody polygons shall be flat and level with a single elevation value for every shoreline vertex.
All features are at or just below (within the vertical accuracy) of the lidar elevation surface.
Remove vertices that are less than 1.5 m apart.
Split all line features at polygon boundaries.
All line features should be one segment, with no breaks within the feature.
All intersections of features shall have a node (a start/beginning, or end/terminating, vertex) at that intersection.
The linear features of the dataset shall create a complete network.
Features less than 1.5 m in length or width shall be removed or merged in with a longer feature.

Table 5. Subset of applicable EDH specifications related to issues discussed in the document.

Attributes and feature class codes in Elevation Derived Hydrography are much simpler than the NHD. To contribute to the 3DHP, NC Hydro will need to contain attributes that conform with 3DHP.

Elevation Derived Hydrography Attributes			
Attribute	**Description**	**Type**	**Examples**
FClass	Feature class (NHD)	short	1
EClass	Feature class (elevation)	short	0
FCode	Feature code (NHD)	long	39000
Desc	Description	text	Lake/pond or user defined.
Source	Elevation source data	text	Description of Lidar source.
Method	Hydrography delineation method	text	Description of the method used for deriving the hydrography.
UserCode	User-defined code	text	Intended to be used as a key to join tables with attributes outside of this specification.
Comments	Free-text space for user comments	text	Free text for user comments.

Table 6. EDH attributes are not as extensive as previous NHD attributes and were considered in HWG recommendations.

NC Hydro

ATLAS Hydrography meets many of the stakeholder's needs by providing a more accurate and consistent representation of hydrography across the state than currently available datasets. It also has potential for networking and ties back to source elevations. The relational database with its connection to the DEQ state business tables is of great benefit. For DEQ, the more accurate and higher resolution geometry benefits NC DEQ in restoration projects, especially in smaller drainage areas. ATLAS Hydrography is still a database designed with a specific purpose to be used inside of a planning tool.

The HWG developed a draft recommended data schema based on conditions as of the creation of this document. The recommended schema considers the needs of stakeholders as well as the available data through ATLAS and the current 3DHP EDH schema and specifications.

Recommended Data Schema

NC Hydro will contain two feature datasets, one containing hydrography and the other a water boundary dataset. The hydrography dataset will contain two feature layers, polyline, and polygon. This differs from ATLAS Hydrography which contains only line features. The tables from ATLAS Hydrography will be included for access to important state hydrography information.

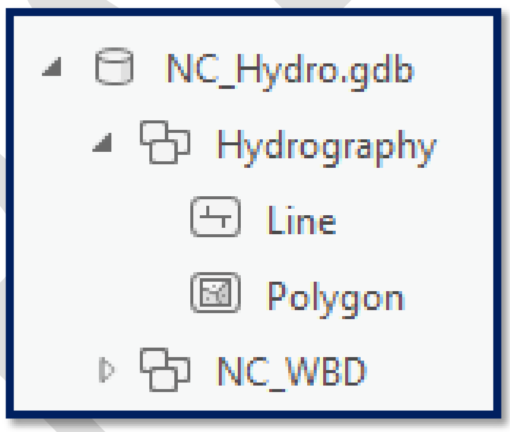


Figure 2. NC Hydro Schema.

Hydrography Dataset

Line Features

Line features in NC Hydro will represent features that are most likely to be intermittent to perennial as well as line features that are necessary to maintain network connectivity such as artificial paths. Line features will also represent the shorelines of waterbodies and wide rivers. For shorelines, topology must be maintained between 2D waterbody features and shoreline features.

NC Hydro Polyline Attributes		
Attribute Name	Data Type	Definition
HYDROID	Text	NCDOT Unique Feature ID. Unique link to NCDOT (ATLAS) data
AUID	Long	Links to NCDEQ Assessment Unit streams.
HUC10AIDX	Text	HSSD Data Link Unique Link to HSSD Data.
AUIDA	Text	NCDEQ data link all features.
WB_ID	Text	Links to 2D waterbody feature class WaterbodyID
HYDROTYPE	Text	Hydrography Feature Type relating to Assessment units and flow intermittency.
FEATURETYPE	Text	Hydrography Feature Type
AUNAME	Text	NCDEQ Assessment Unit Name
INSTATE	Text	Is feature in North Carolina.
HUC12	Text	12-digit USGS WBD subbasin code
AUNUMBER	Text	NCDEQ Assessment Unit Number
GNIS_ID	Text	Identifier for geographic objects in the US issued by the USGS.
GNIS_NAME	Text	Textual name for geographic object.
BIMSINDEX	Text	NCDEQ Basinwide Information Management System Number
BIMSCLASS	Text	BIMS Water Quality Classification(s)
FeatureYear	Long	Year feature geometry was created/last edited
Method	Text	Description of the method used for deriving the hydrography.
Shape_Length	Float	Length of individual polyline features in feet

Table 7. NC Hydro attributes for streamlines, connectors, artificial paths, and waterbody shorelines.

Polygon Features

Ponds, lakes, and large rivers will be represented as polygon features.

NC Hydro Polygon Attributes		
Attribute Name	**Data Type**	**Definition**
WaterbodyID	Text	Waterbody ID generated by NC Hydro
HYDROID	Text	NCDOT Unique Feature ID. Unique link to NCDOT (ATLAS) data
AUID	Long	Links to NCDEQ Assessment Unit streams.
HUC10AIDX	Text	HSSD Data Link Unique Link to HSSD Data.
HYDROTYPE	Text	Hydrography Feature Type relating to Assessment units and flow intermittency.
FEATURETYPE	Text	Hydrography Feature Type
AUNAME	Text	NCDEQ Assessment Unit Name
INSTATE	Text	Is feature in North Carolina.
HUC12	Integer	12-digit integer code for the HUC8 subbasin
AUIDA	Text	NCDEQ data link all features.
AUNUMBER	Text	NCDEQ Assessment Unit Number
GNIS_ID	Text	Identifier for geographic objects in the US issued by the USGS.
GNIS_NAME	Text	Textual name for geographic object.
FeatureYear	Long	Year feature geometry was created/last edited
Method	Text	Description of the method used for deriving the hydrography.
Shape_Area	Float	Area in square feet.
Shape_Length	Float	Polygon perimeter in feet.

Table 8. NC Hydro attributes for lakes, ponds, and wide streams represented as polygons.

Many of the attributes from ATLAS Hydrography will be brought over to NC Hydro. AUID, AUNAME, AUIDA, and AUNUMBER provide links back to important NC DEQ data. HUC10AIDX field provides a link back to the HSSD data. HYDROTYPE and FEATURETYPE attributes will be brought in from ATLAS. These attributes can be cross walked to create the FCode attribute and domain, which is a part of EDH.

EDH FCode will not be maintained in NC Hydro, but the table below demonstrates the cross walk to match NC Hydro feature attributes to EDH FCodes. Some of the Feature Types below do not currently exist in ATLAS, but if added, would enhance the ability to accurately crosswalk features to EDH. These missing attributes are noted with an asterisk (*) below.

ATLAS/NC Hydro Attributes		3DHP			
HydroType	**FeatureType**	**Fcode**	**Description**	**Polyline**	**Polygon**
Stream/River-Single	Mainstem	46000	Stream/river	x	
Stream/River-Single	Tributary	46000	Stream/river	x	
Stream/River-Double	Mainstem	46000	Stream/river	x	x
Lake/pond	Mainstem	39000	Lake/pond	x	x
Lake/pond	Tributary	39000	Lake/pond	x	x
Atlantic Ocean	Coastline*	44500	Sea/ocean		
Null	Artificial path	55800	Artificial Path	x	
Stream/River-Single	Drainageway	46800	Drainageway	x	
Null	Modeled Connector*	33400	Connector	x	

Table 9. Comparison of NC Hydro HydroType and FeatureType as they relate to 3DHP FCodes

There are three feature name attributes that are in the proposed NC Hydro database: AUNAME, GNIS_NAME, and GNIS_ID. The NC DEQ regulatory name (AUNAME) reflects the extent of regulation of the feature and has a regulatory name format such as *Abbotts Creek (including Lexington-Thomasville Water Supply Reservoir at normal reservoir elevation, Tom-A-Lex Lake).* The GNIS_NAME is the official USGS geographic name for the feature. The GNIS_NAME for the above example would be "*Lake Tom-A-Lex*." The GNIS_NAME is the name most often needed for cartographic purposes. GNIS_ID is a unique identifier for the geographic name. The GNIS_ID could give users cartographic options when annotating features for display purposes. GNIS_ID is a permanent identifier, while the GNIS_NAME may change, so maintaining this attribute requires periodic review of USGS data for changes.

Water Boundary Dataset

The Water Boundary Dataset will represent watershed boundaries. This dataset will not initially match the NHD WBD and should not be confused with the national layer. Ultimately, the HWG hopes that as NC Hydro data is adopted into the national WBD, the two layers will match. The WBD dataset is not a feature of ATLAS and must be created and attributed for NC Hydro.

The HSSD surface flow models were processed using the NHD HUC10 WBD as an initial processing region. After a HUC10 region surface flow model was created, HSSD generated an updated watershed boundary. In regions of the state with significant elevation relief, the NHD WBD and the updated watershed were very similar. In regions of the state with less elevation relief, mostly east of I-95, the boundaries diverged. The NC Hydro WBD will reflect watersheds delineated using HSSD elevation datasets. The NC Hydro WBD will contain three feature layers: HUC8, HUC10, and HUC12. Each will have the following attributes.

HUC 12, 10, and 8 Attributes		
FeatureClass	**Type**	**Description**
HUCID	Text	Unique identifier for feature
NCHUC	Text	NC HUC number should match USGS in most cases (8, 10, or 12 digits)
USGSHUC	Text	USGS HUC number that intersects the majority of the feature
StateName	Text	NC HUC name should match USGS in most cases
USGSName	Text	USGS HUC name that intersects the majority of the feature
Model Date	Year	Year geometry was created
Shape_Area	double	area of the feature
Shape_Length	double	perimeter of the feature

Table 1010. WBD Feature Class Attributes

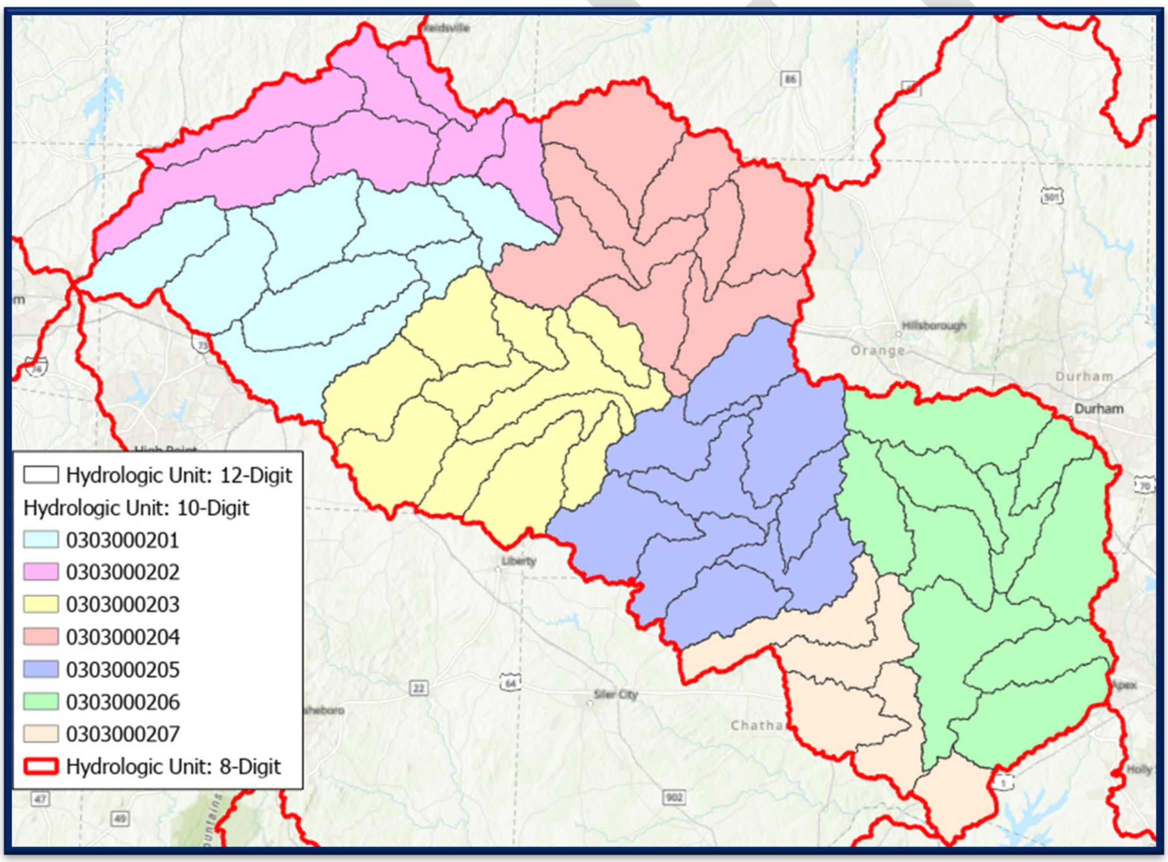


Figure 3. Relationship between 8, 10, and 12-Digit HUCS. Each watershed level nests within another, with the 8-Digit HUC the largest, and the 12-Digit HUC the smallest.

NC Hydrography Issue, Gaps, and Recommendations

Because ATLAS hydrography is now the best available data for the state, the HWG is using the ATLAS Hydrography as a starting point for a more accurate hydrography dataset that would become NC Hydro. HWG Stakeholders have identified shortcomings in ATLAS Hydrography that must be addressed in order to meet the vision of NC Hydro. The HWG has identified the following needs and gaps between ATLAS data and NC Hydro specifications.

Polyline Issues

Stream Segmentation

When the HSSD data is created, a stream segment exists between every preferential flow path confluence. NHD and 3DHP specifications call for these segments to be combined into a single segment between remaining confluences. Combining the segments into a single reach will produce a smaller and faster dataset. Refer to the images below to understand the common length of segments in the HSSD vs NHD/3DHP.

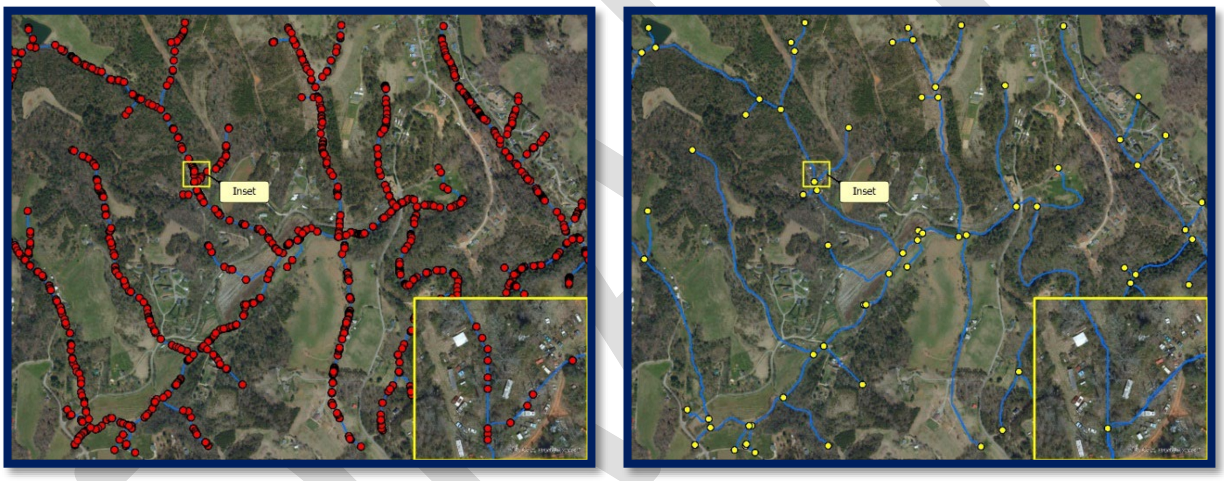


*Figure 4. **Left:** In a small sample area, ATLAS data contains more than 9000 stream segments between each point, many of which are smaller than the length of a car. **Right**: The same dataset with simplified reaches between confluences contains only 42 segments.*

As the HSSD data is trimmed to reflect the modeled intermittent and perennial streams, the relic segmentation is preserved. Performing analysis on the segmented dataset can be difficult-to-impossible, given the number of records in the database.

If reaches are combined between confluences, linkage back to HSSD tables will be lost (although the original HSSD will remain as a complete model no matter what is done to NC Hydro). Analysis and performance of both desktop and data services will increase with fewer reaches in the database. Combining segments will maintain a dataset more likely to conform to 3DHP specifications. However, 3DHP specifications call for continuous reaches between confluences, and DWR assessment units do not always end at confluences. Reaches will need to be split between confluences to accommodate DWR AUIDs.

User's preference for combined reaches between confluences was overwhelming. Those who did prefer a segmented reach could make use of the original HSSD data for small areas of need.

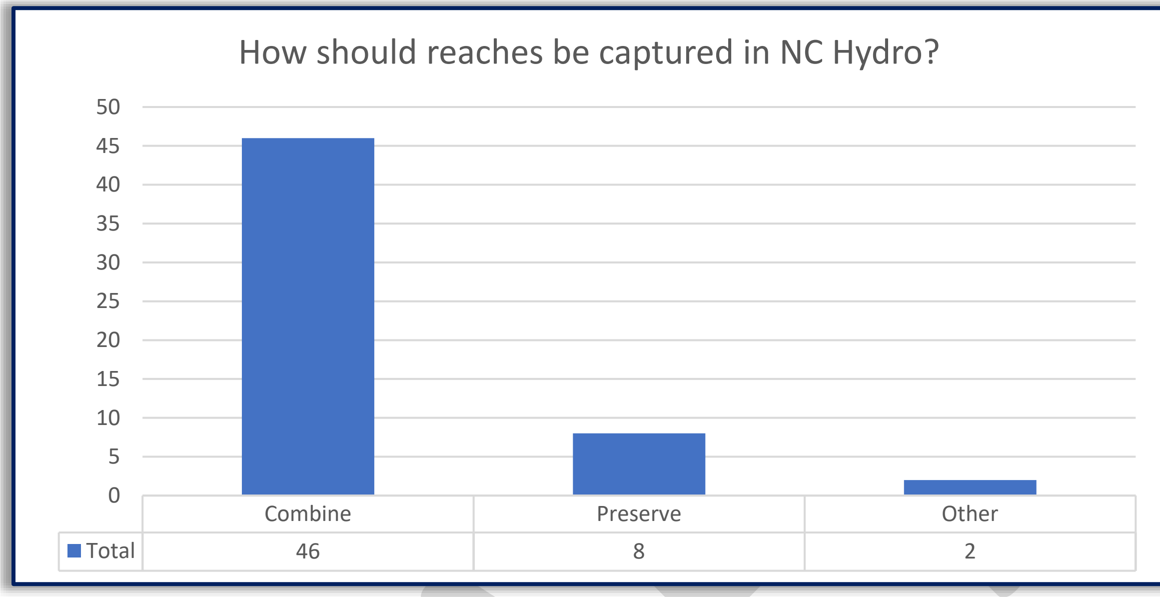


Figure 5. HWG survey results: should reaches be combined between confluences or should small segments between confluences be preserved?

<u>Recommendation:</u> Combine segments between confluences. Reaches will be split where needed to represent breaks in DWR Assessment Units.

Smoothing

The original HSSD data was created from a raster model of the earth's surface and has a zig-zag appearance at larger scales. Smoothing the lines creates a more cartographically pleasing appearance. Smoothing changes the location of the linework but can be set within tolerances to preserve accuracy of the data. Time is required to smooth lines while preserving accuracy.

There is a danger in smoothing ATLAS line work. The HUC10AIDX attribute would not associate with the correct drainage information or elevation data in the HSSD_RCHPT00_SRC00 table which relates back to the 10ft DEMs created for HSSD. The power in this data is its relation back to the elevation, and this could be broken. There are techniques to smooth linework. USGS is using a smaller grid size for its source hydrography product, 1-meter. Contractors are required to smooth the linework before submittal to USGS with vertex spacing no smaller than 1.5 meters. This gap between ATLAS and NC Hydro represents a significant time and dollar investment to bring the data to meet stakeholder needs.

Figure 6. The left image shows the raw rasterized ATLAS data, the middle image shows a smoothed representation on top of ATLAS data, and the right image shows the smoothed data.

Most users indicated that smoothed lines better fit their business needs. Survey respondents noted that they primarily use the dataset for visualization. Many noted that this data is used widely to display stream features to the public, and representing streams as curves instills more trust in the map data because people are more used to seeing stream data represented as smoothed lines. Others noted that natural streams do not tend to have zig-zag features, so smoothing better reflects the natural centerline of the stream. Some respondents also noted that they use the data to calculate distances and felt that smoothed lines would allow them to get a more accurate measure of on the ground distance. For the few respondents that wanted the zig-zag appearance preserved, the primary reason was to maintain accuracy.

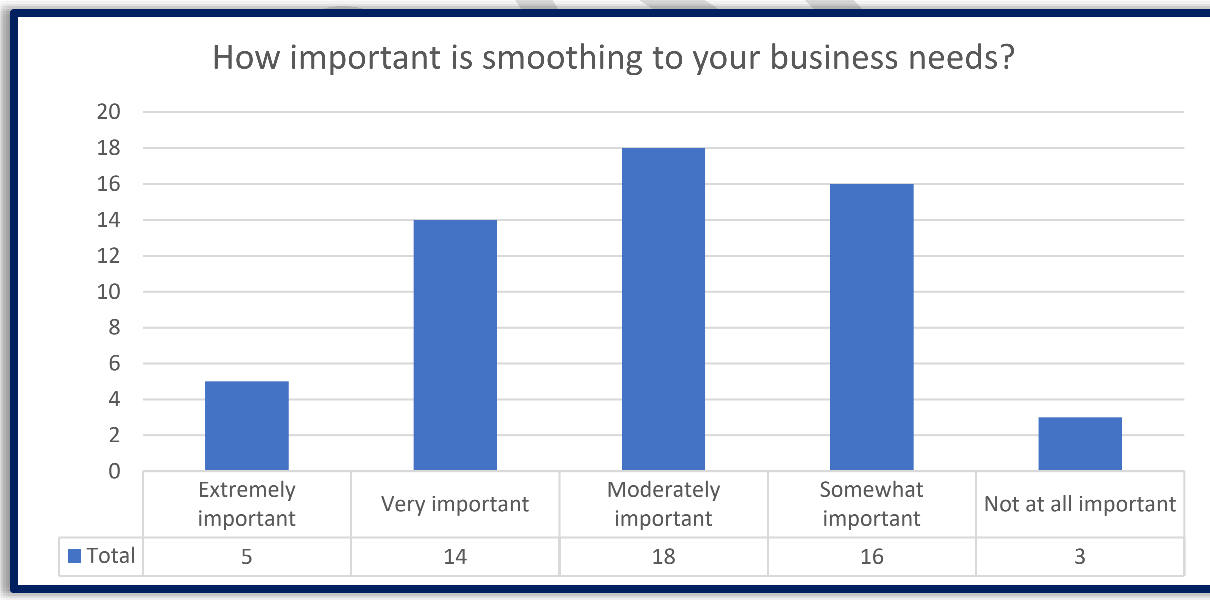


Figure 7. HWG Survey Results: Users rated the importance of cartographic smoothing.

<u>Recommendation:</u> Smooth lines for a cartographic appearance while maintaining accuracy within EDH specifications when possible.

Shorelines

The representation of a waterbody in ATLAS is not as a polygon but as a line feature. Stakeholders have agreed that waterbodies should be represented as polygons. Shorelines as line features could be retained from ATLAS, or they could be removed to be more closely aligned with NHD and 3DHP specifications. If shorelines are retained as line features, all new lakes, ponds, and double line streams would need to be represented both as a line feature and a polygon waterbody.

If maintained, shorelines should be attributed to differentiate them from streams or artificial paths. Having shorelines and artificial paths in a single dataset could make networking through a dataset more difficult. However, ATLAS requires both shorelines and streamlines within the same dataset. The NC Hydro dataset could handle this problem by separating shorelines into their own feature class. This issue requires more discussion within the HWG.

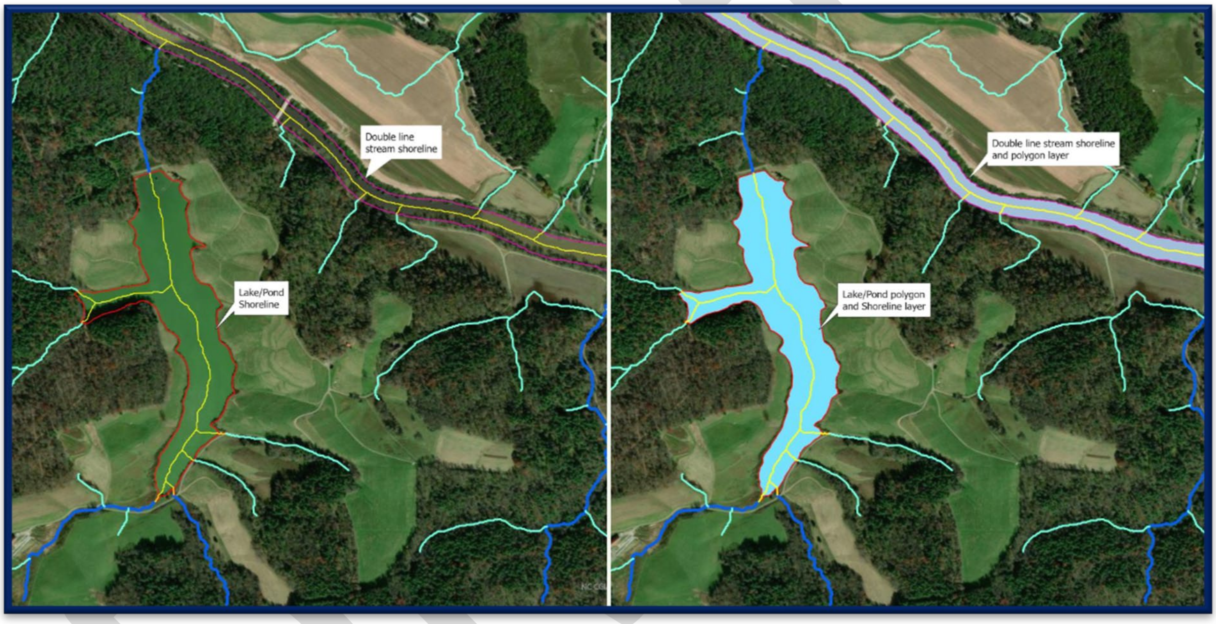


Figure 8. Left: Example of shorelines as polylines only. Right: Example of shorelines as both polylines and polygons. Note that the polygon edge is the same as the shoreline polyline.

Survey respondents were split between the need for polygons only and polygon plus polyline representation of waterbodies. Important use cases exist for both feature types including area calculations of lakes and linear calculations of shorelines. Many users who expressed a preference for both feature types noted that they use each feature type for different use cases, so having both would eliminate the need to convert one to another.

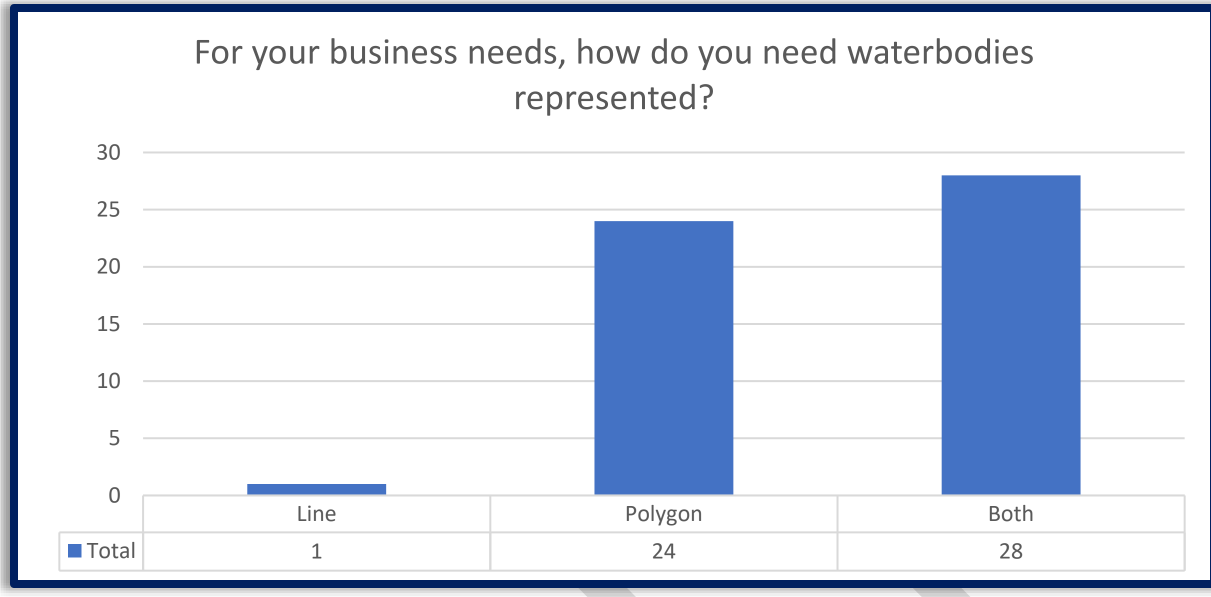


Figure 9. HWG Survey Results: Users answered how polygons must be represented to support their business practices

Recommendation: Develop both a shoreline feature in the polyline dataset as well as a polygon waterbody feature in the polygon dataset. Topology must be maintained between the two features.

Waterbody Issues

Waterbody Size

When visually comparing ATLAS Hydrography with NHD, the density of ATLAS stream/river line features is greater, but there is a lack of small lake/pond shoreline features, and double bank river/streams are not as extensive. This gap is due to ATLAS Hydrography reflecting the NCFMP collection specification of a 2-acre minimum on lake/ponds and 100-foot width on 2D stream/rivers, while existing NHD has a ¼ acre lake/pond minimum and 50-foot 2D stream/river collection specification. For a comparison, ATLAS Hydrography contained 30% of the lake/ponds as the NHD for the same 10-digit watershed boundary dataset in the Neuse River basin.

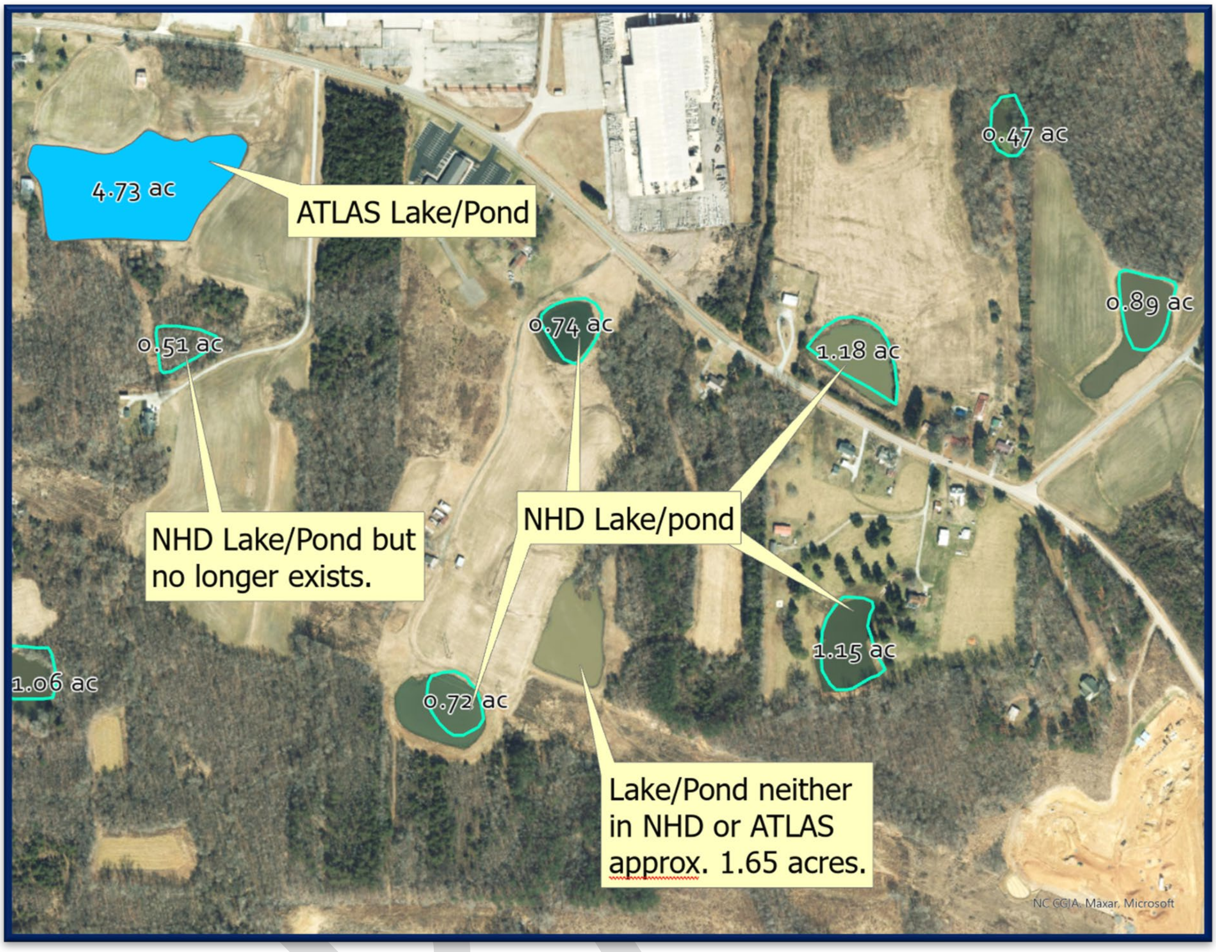


Figure 10. Example of ATLAS waterbody size vs. NHD size. Note also that NHD waterbodies are not representative of current ground conditions.

Stakeholders acknowledge that NHD lake/pond features are not perfect. In the above example, there are NHD lake/ponds features that no longer exist in the current imagery but there are lake/ponds in the imagery that do exist but are not part of the he ATLAS Hydrography. Many of the stakeholders have been using NHD for local regulatory purposes. Losing this feature could be an issue for the local communities. Stakeholders overwhelmingly indicated that the ¼ acre specification best met their needs.

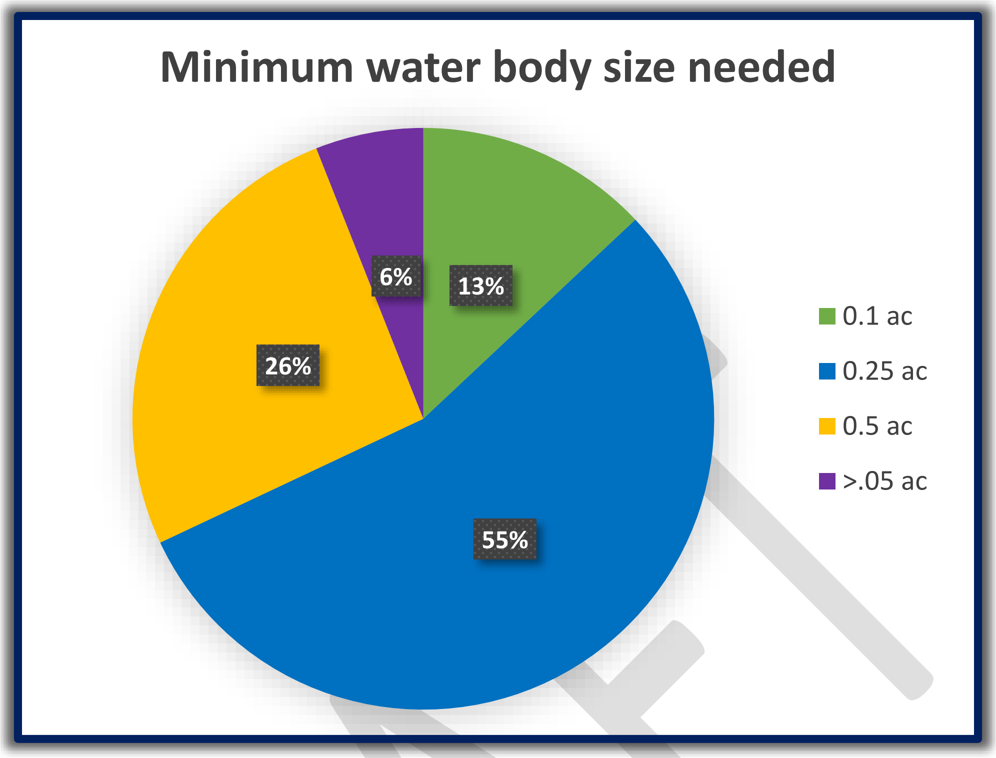


Figure 11. Survey Results- Minimum waterbody size

Aligning the NC Hydro minimum waterbody specification with the USGS EDH ¼ acre for lake/ponds and 50' for double line streams would meet most of the stakeholder needs. Collection of lake/pond features are difficult below the 2-acre threshold, and USGS has mentioned that it has been difficult for the contractors of EDH to collect these features. Collection of waterbodies might need some additional research. A combination of elevation data and recent imagery could prove useful. Adding these waterbodies would also require adding shorelines to the polyline dataset.

***Recommendation:* Add waterbodies that meet the minimum ¼ acre size to the dataset.**

2D Rivers

Per NHD specifications, rivers and streams wider than 50 feet are collected as a waterbody, often referred to as a "double line stream." The specification for the existing 24K NC stream data produced around 2007 was to create double line streams from streams with a width greater than 40 feet. EDH specification are 50 feet.

ATLAS stream data does not continue double line stream polygons as far upstream as the NHD or current 24K NC stream data. HWG members have expressed a desire to maintain or increase data density. Additional work will be required to reach bring ATLAS hydrography to the current EDH specifications.

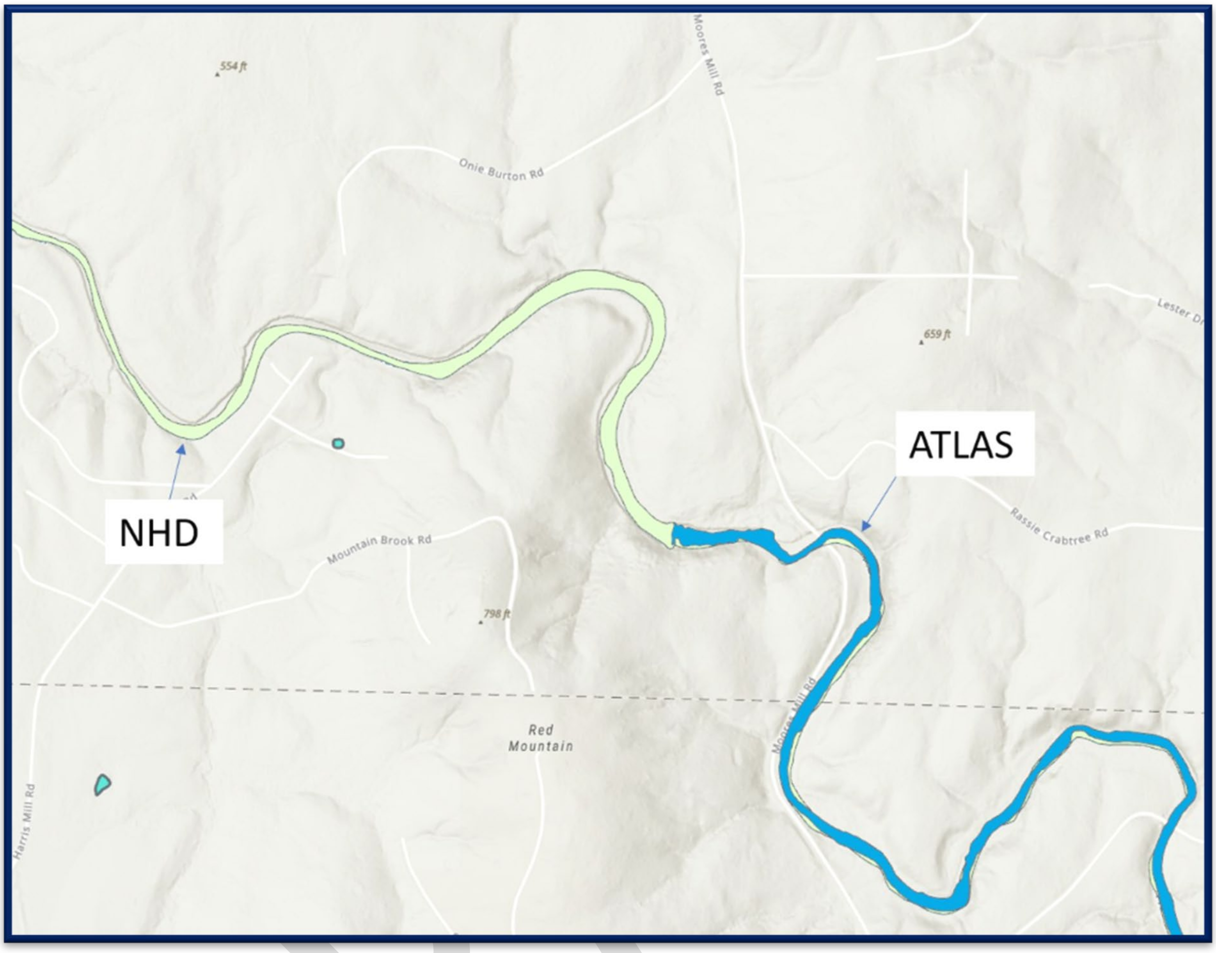


Figure 12. Due to differences in minimum stream width specifications, ATLAS hydrography does not travel as far up the watershed as NHD.

Most survey respondents preferred to maintain the existing 40’ minimum width specification used for the 2007 western county hydrography dataset. Consistency with existing and national datasets was a commonly voiced stakeholder need.

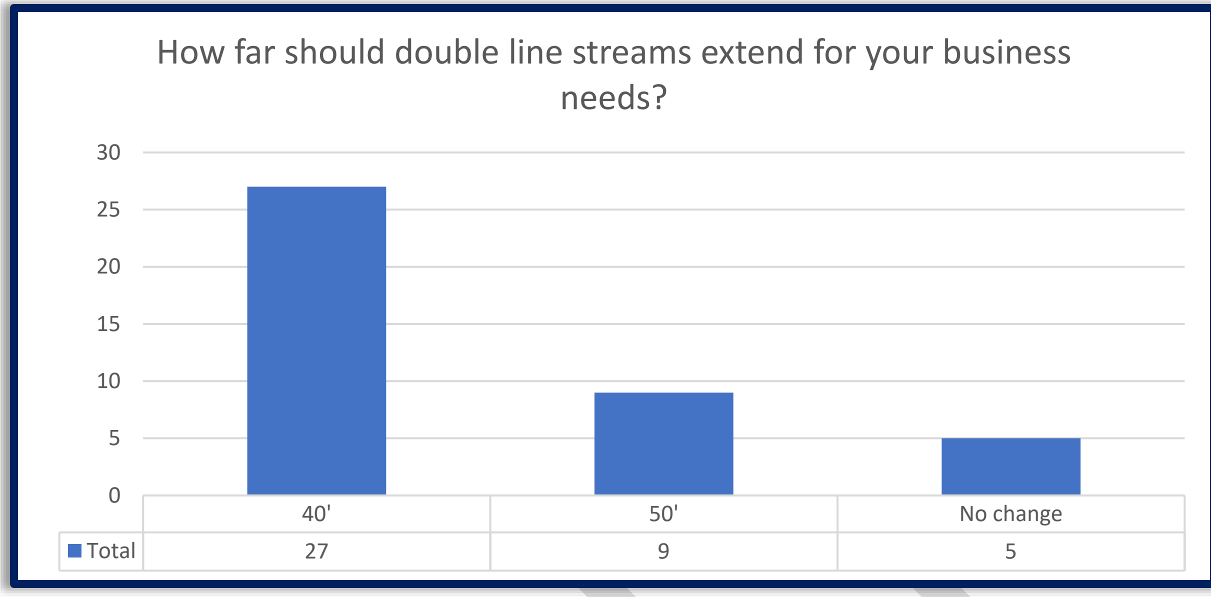


Figure 13. HWG Survey Results: Users rated their preference for the minimum width required to map a stream as a polygon area.

<u>Recommendation:</u> Add streams and rivers represented as polygons to match current EDH and 40-foot Western NC Hydrography specifications.

The EDH specifications are outlined below and can be found in the USGS *Elevation-Derived Hydrography Representation, Extraction, Attribution, and Delineation Rules.*

- **EDH Lake/pond collection specifications**
  - is greater than or equal to 100 feet (30 meters) along the shortest axis (or approximately 0.1 hectare [0.99 acre]).
- **EDH Stream/river collection specifications**
  - For EDH feature collection, if shortest axis of stream/river is less than 50 feet (15 meters) but greater than or equal to 20 feet (6 meters) for a distance less than 0.6-mile (1 kilometer) and is connected at both ends to a 2-dimensional (polygon) stream/river,
    then stream/river is represented as a 2-dimensional (polygon) basic feature object.
  - less than 50 feet (15 meters) but greater than or equal to 20 feet (6 meters) for a distance greater than or equal to 0.6-mile (1 kilometer), or less than 20 feet (6 meters) regardless of distance, and is connected at both ends to a 2-dimensional (polygon) stream/river,
    then stream/river is represented as a 1-dimensional (line) basic feature object,
  - greater than or equal to 50 feet (15 meters) but less than 80 feet (24 meters) for distance greater than or equal to 0.6-mile (1 kilometer), or greater than or equal to 80 feet (24 meters) regardless of distance, and is connected at both ends to a 1-dimensional (line) stream/river,
    then stream/river is represented as a 2-dimensional (polygon) basic feature object.

Feature Attributes and Network Connectivity

Adding new features to a dataset this large is not trivial. With the connections ATLAS Hydrography has to other tables and with underlying elevation data, data changes could lead to a host of questions that need to be answered. If waterbodies are added, they could be disconnected from the greater river basin network. This disconnection could result in the need for HSSD model rerouting or ATLAS table regeneration. Because the HSSD/ATLAS data is so dense with drainageways, the likelihood of that happening is small, but it must be taken into consideration.

The following section addresses the technical hurdles that must be faced when adding features to an existing dataset, including attribution changes, and the potential need to add features in other datasets than the one just updated.

Hanging Waterbodies

When the hydrographic network was modeled, preferential flow paths were removed upstream of the modeled intermittent stream origin. Sometimes a waterbody exists upstream of the modeled origin and is left disconnected from the network. Artificial paths could be added back to the NC Hydro layer to connect these waterbodies to the stream network. This added section should be attributed as an artificial path unless new models or fieldwork show that the stream does extend to the hanging waterbody.

Figure 14. Preferential flow path is reclassified as modeled connector to connect lake/pond to existing hydrography network.

The overwhelming majority of survey respondents agreed that hanging waterbodies should be connected to the network. Many respondents noted that it is important to attribute these connections so that they are not interpreted to be streams for regulatory purposes.

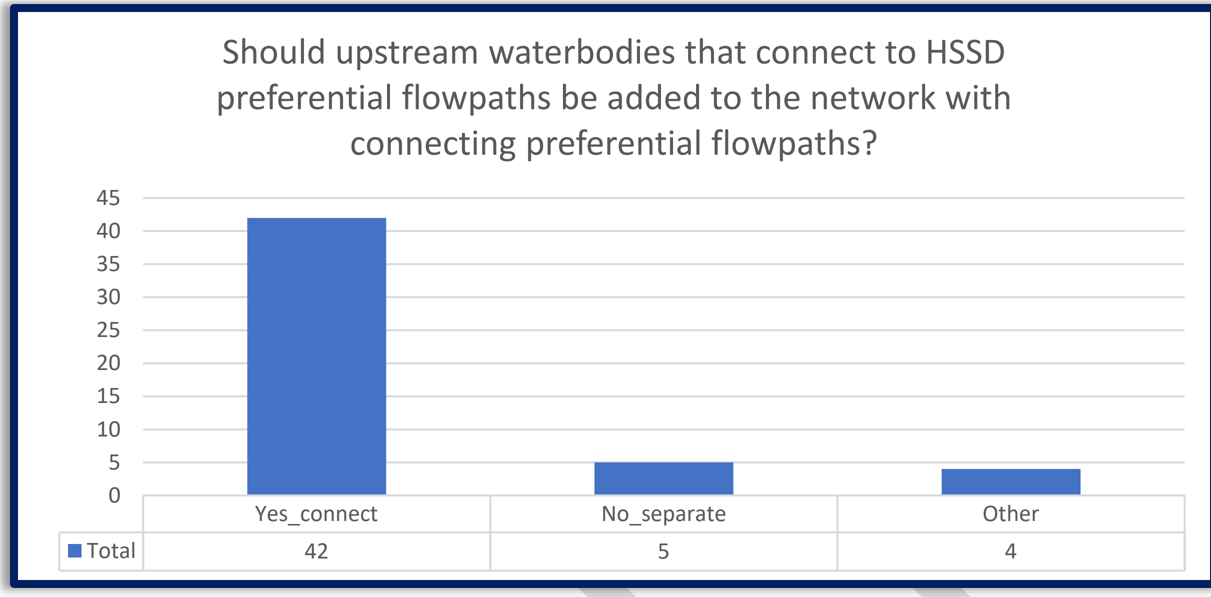


Figure 15. HWG Survey Results: Users were asked whether ponds located above the modeled stream network should be connected through modeled connectors.

***Recommendation:* where preferential flow paths exist, connect hanging lake/ponds to the stream network with an attribution of modeled connector.**

Missing In-Line Waterbodies

Waterbodies less than 2 acres were not mapped as part of the ATLAS project. Many waterbodies exist within the stream network that would be added as part of the project to add all waterbodies greater than ¼ acre. There are multiple cases and process steps to address these new features. For these in-line new waterbodies, the attribution on the stream would need to be changed to an artificial path inside the new waterbody and preferential flow path reclassified as modeled connector.

Case 1: New waterbody must be mapped in between a hanging waterbody and the start of the network.

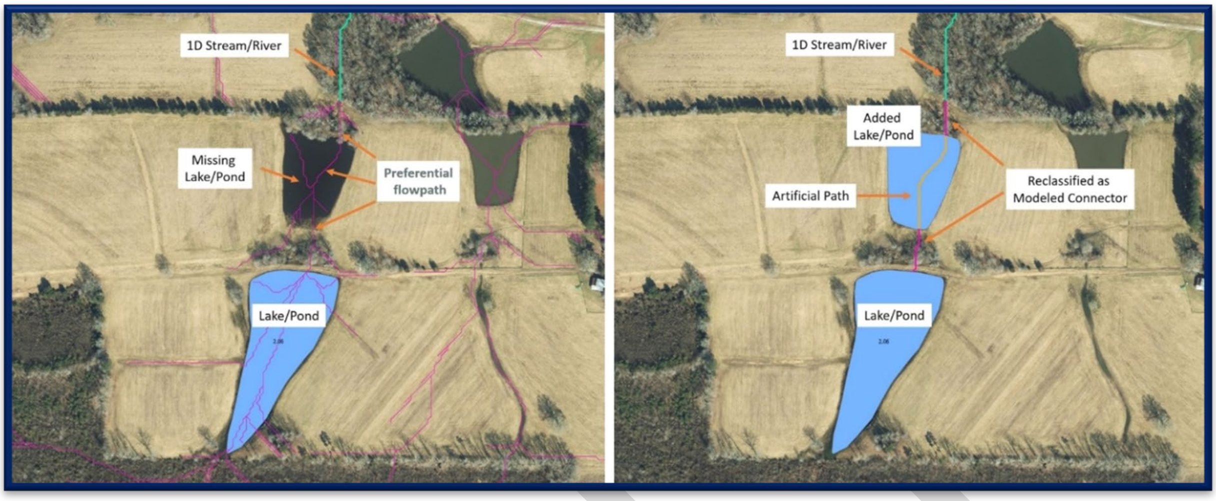


Figure 16. Adding missing in-line waterbodies would also require bringing in the intersecting preferential paths and changing the feature class.

<u>Recommendation:</u> In this case, the new waterbody will need to be added to the polygon dataset. A shoreline feature will be added to the polyline dataset. Modeled connectors between the headwater pond and missing pond as well as the missing pond and stream origination point will be added. Finally, the artificial path through the new pond will be added.

Case 2: New waterbody is added upstream of most upstream feature in the network. This could be upstream of a pond or of the stream origin point.

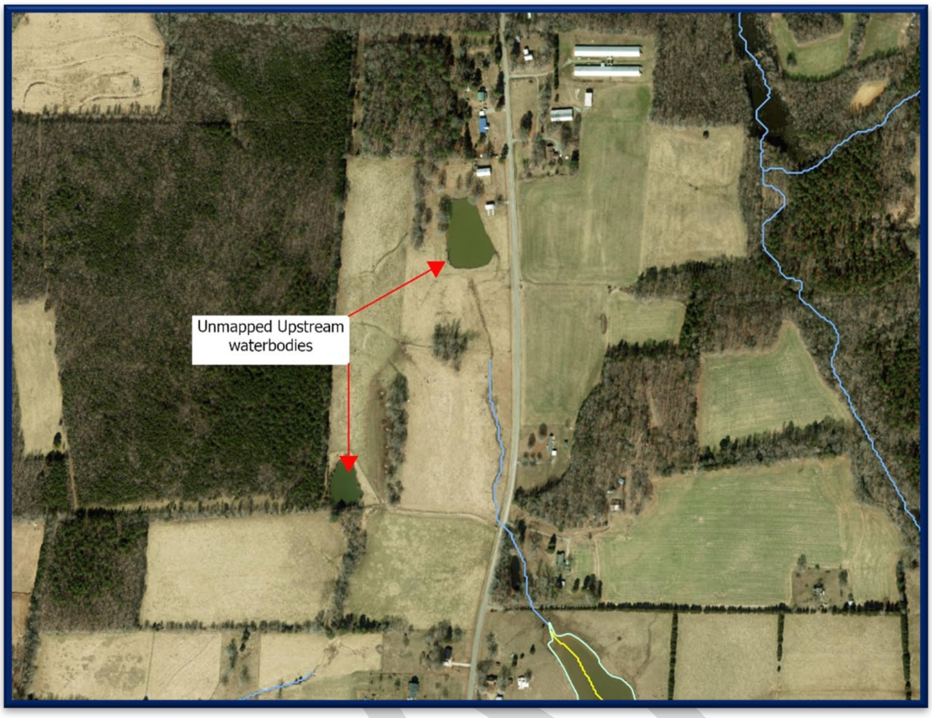


Figure 17. Example of waterbodies above the most upstream feature of the network.

<u>Recommendation:</u> In this case, the new waterbody will need to be added to the polygon dataset. A shoreline feature will be added to the polyline dataset. Modeled connectors between missing pond and network origination point will be added.

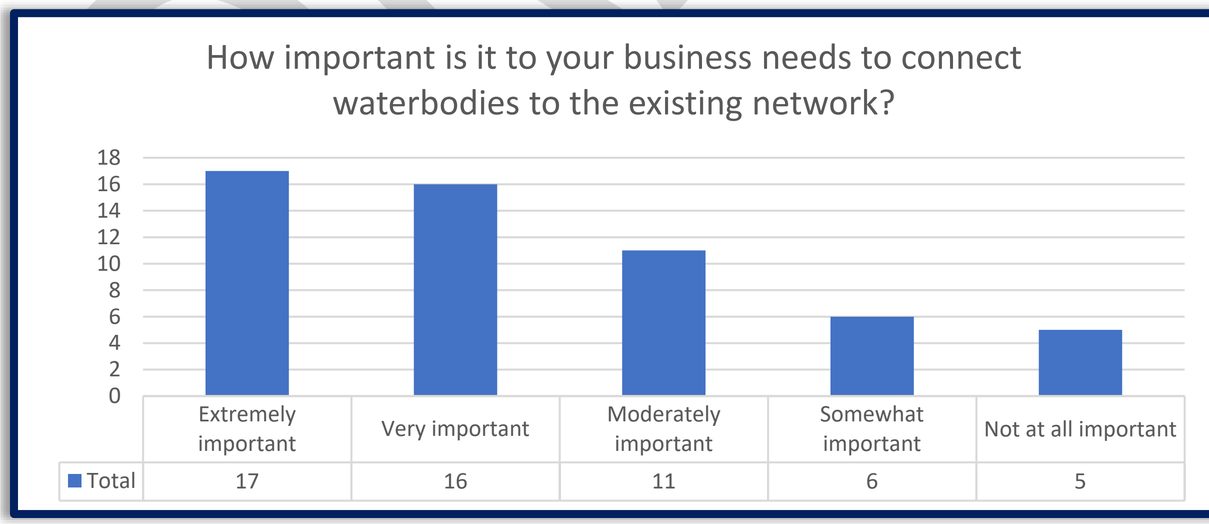


Figure 18. HWG Survey Results: Users were asked how important it was to connect waterbodies to the stream network.

Case 3: New waterbody is added in line on an existing stream.

In many cases, there are existing waterbodies along ATLAS streams that were not captured because they fall below the 2-acre minimum. When these features are added, they will trigger edits to add shoreline features, split stream features, and change stream attributes to artificial paths.

Figure 19. Example of waterbody to be added along the existing stream network.

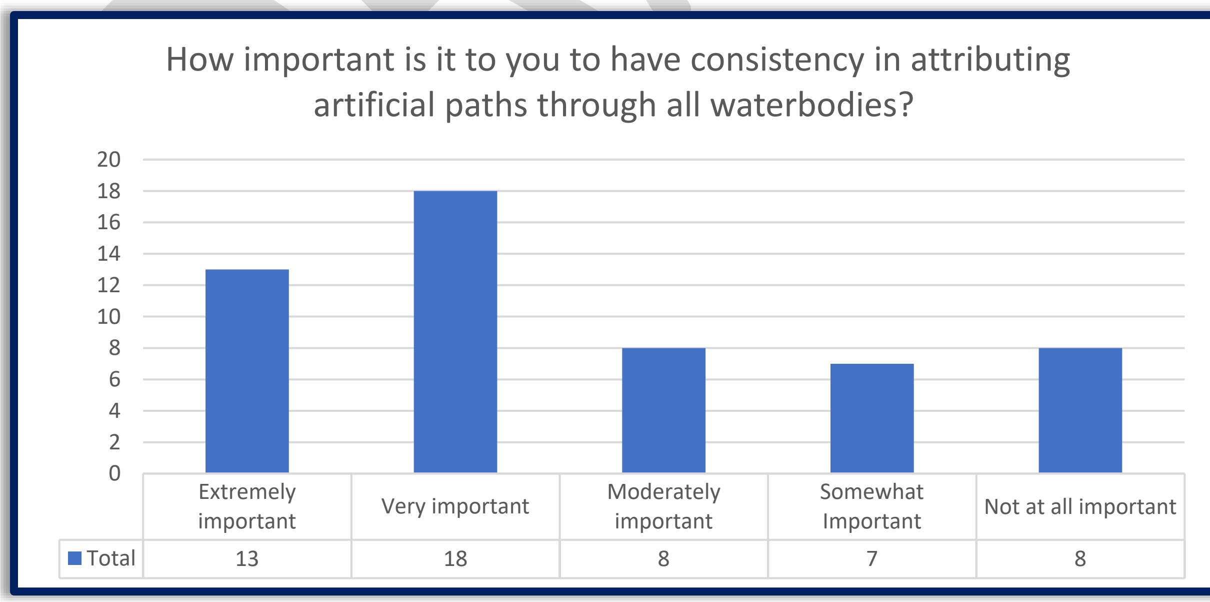


Figure 20. HWG Survey Results: Users were asked whether data should be edited to add artificial paths through all waterbodies.

Recommendation: ***In this case, the new waterbody will need to be added to the polygon dataset. A shoreline feature will be added to the polyline dataset. The section of stream running through the waterbody will be attributed as an artificial path rather than stream/river.***

Case 4: New waterbody is added that has no discernable overland connection to the network. Sinkholes are a good example of this case. Outlets may be unclear and need field verification. These waterbodies may have an underground connection or a piped connection, but overland connections do not exist or are not evident.

Figure 21. ***Left-*** *modeled stream network shown on aerial photography of an area of karst topography.* ***Right-*** *hillshade representation of sinkhole area showing ponds with no surface outlet.*

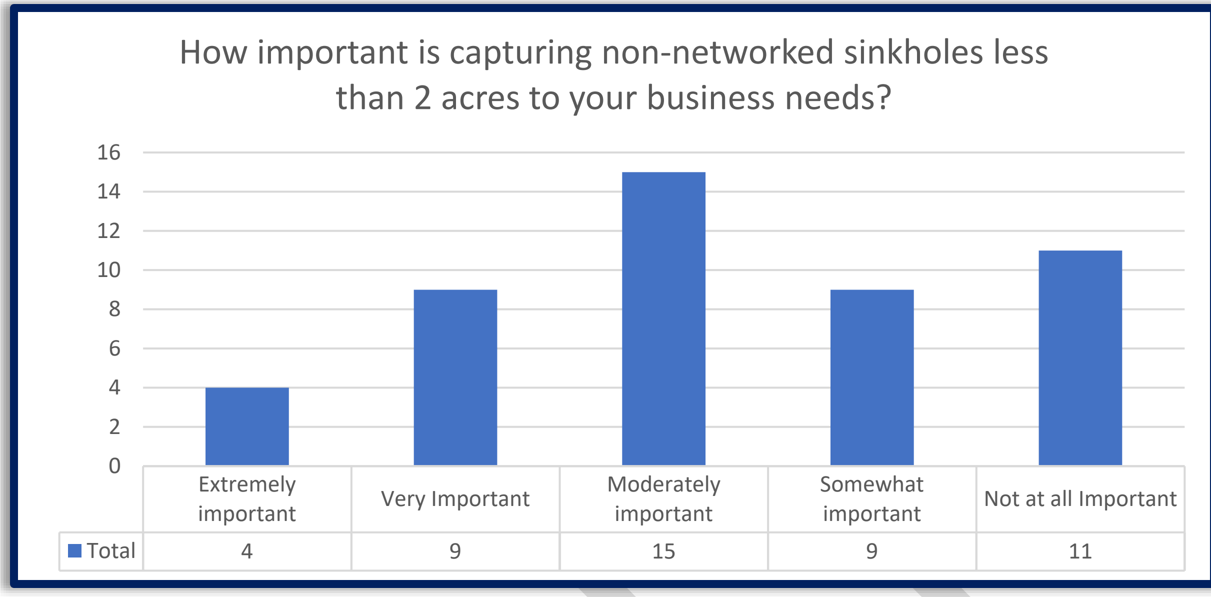


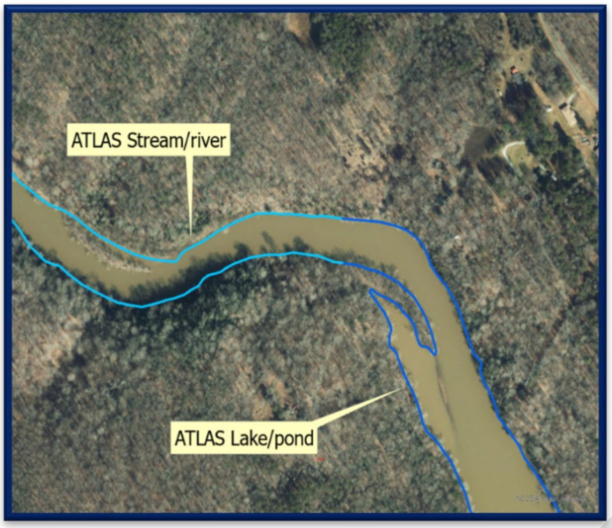
Figure 22. HWG Survey Results: Users were asked whether capturing features like sinkholes with no surface outflow was important to their use cases.

Recommendation: ***In this case, the new waterbody will need to be added to the polygon dataset. A shoreline feature will be added to the polyline dataset. A modeled connector will not be added to the stream network unless a connection is confirmed through field or additional investigation.***

Survey respondents felt that it was important to map all ¼ acre minimum waterbodies, regardless of location, connect them to the network, and attribute features properly so that the dataset can be used for regulatory purposes.

Waterbody Differentiation

The process to close multiple shoreline polylines to create a polygon creates a single waterbody polygon. Because ATLAS is only a polyline feature class, the break where a double bank stream flow into a lake is only depicted on what would be the shoreline of the feature. If a polygon was to be created, a closure line would need to be added to the feature creating two separate polygons. This process is not easy to automate and would likely require much manual effort.



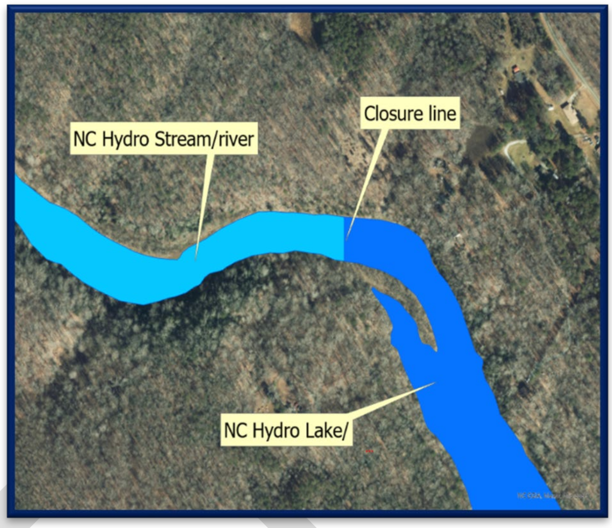


Figure 23. ***Left*** *- ATLAS attribution of shorelines illustrating change from a river assessment unit to a lake assessment unit.* ***Right-*** *polygon representation demonstrating the need to split the stream polygon and lake polygon at the assessment unit change.*

Stakeholders indicated that it was important to differentiate these features. Some noted that splitting the features makes selecting the entire stretch of waterbody more difficult and that the location of the split was arbitrary if it is considered to be the exact point where a river becomes a lake. However, the split points would be based on DWR regulatory descriptions, and not exact points meant to differentiate stream and lake, an important fact for metadata.

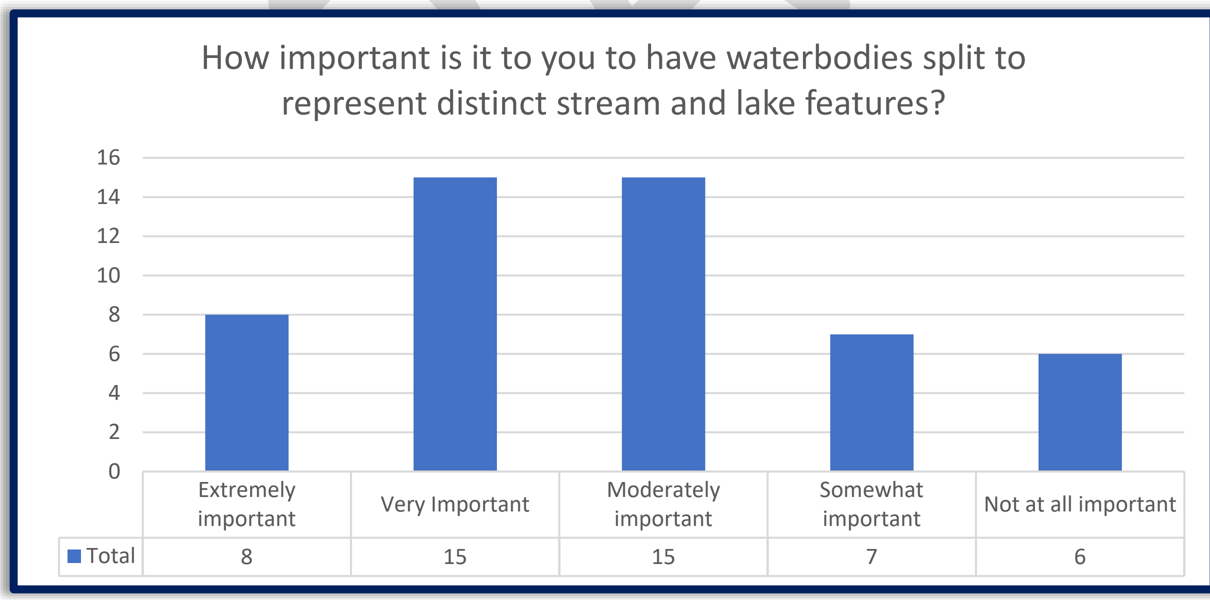


Figure 24. HWG Survey Results: Users were asked how important it was to split river polygons from lake polygons.

DWR's regulatory descriptions split reaches of stream as well as lakes. Both stream lines and polygons will need to be split to conform with DWR's assessment units and names. These splits will not meet the specifications for the EDH/NHD, so additional work would be required to merge these split sections if the layer is to be incorporated into the EDH.

Sometimes, splitting a lake could become very complicated.   The image below shows assessment units as distinct colors. Note that splits may be needed not only across a lake, but through its center as well. this kind of interpretation will be time intensive. A copy of waterbodies split by AUID will need to be merged by GNISID if they are to be added to the 3DHP.

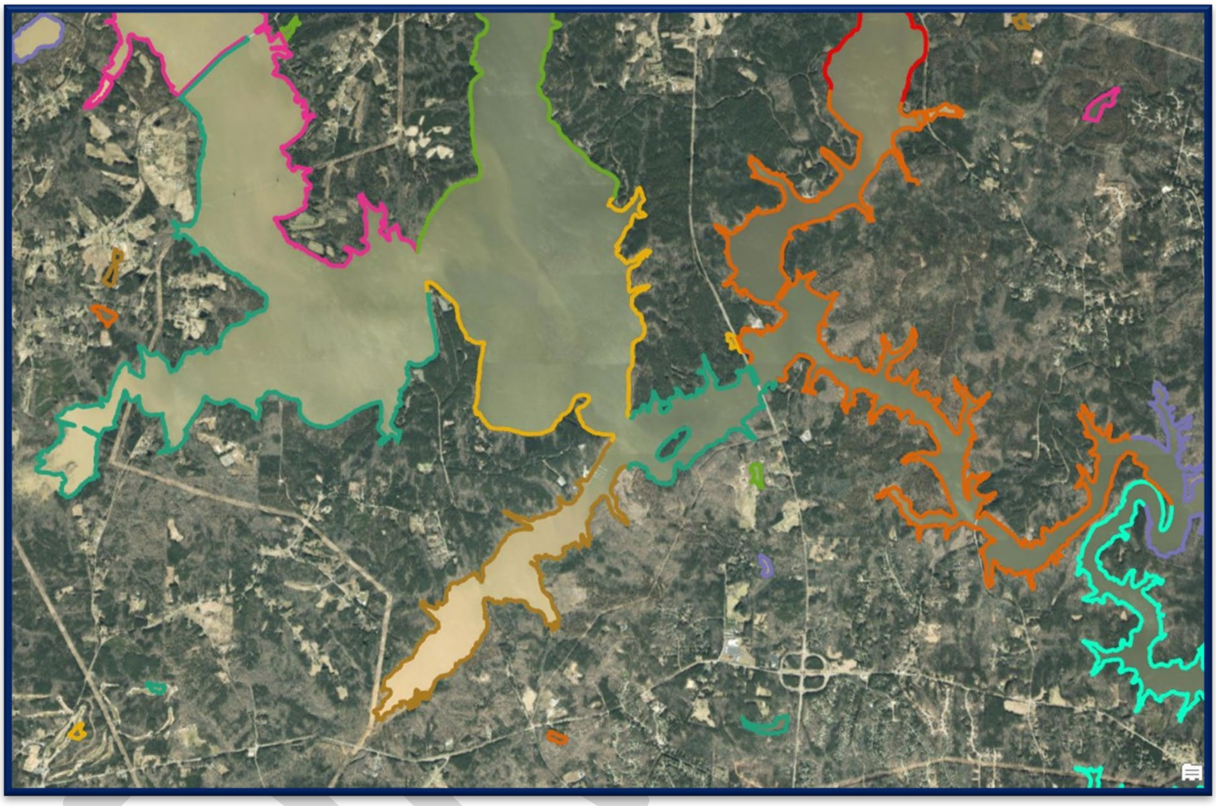


Figure 25. Example of DEQ assessment units on different shorelines of a lake feature. Splitting the lake along assessment units would be difficult.

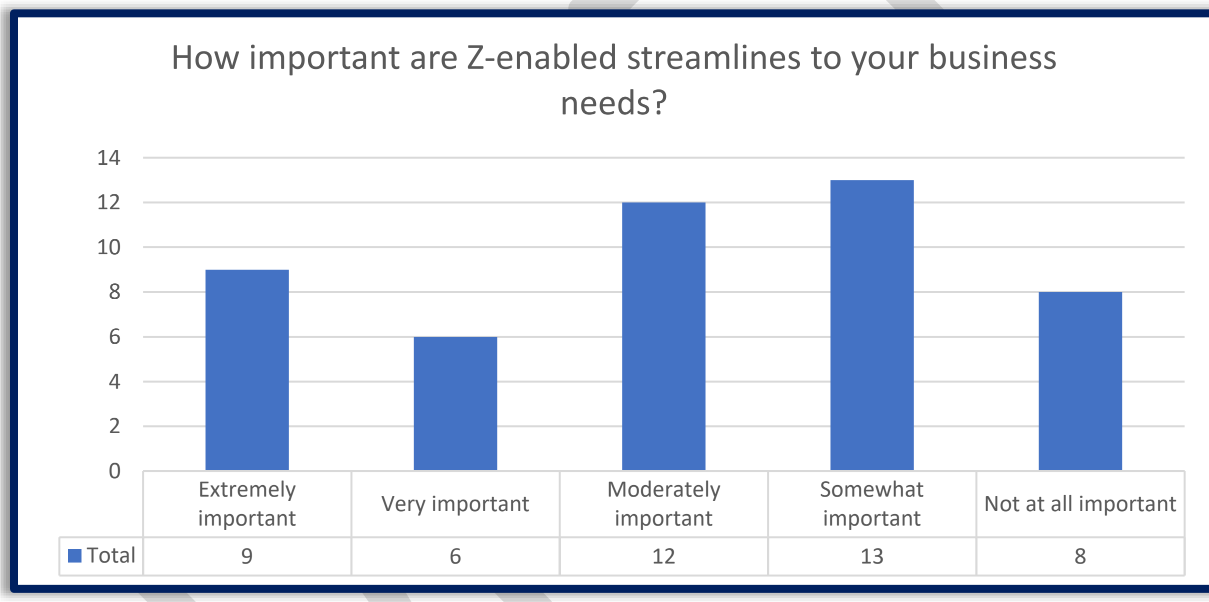
Recommendation: Split waterbody features to represent distinct rivers and lake features, and split complex lake features with multiple shoreline assessment units into distinct units.

Z Enabled Features

The move to the 3DHP includes a specification for Z-values on streams and waterbodies. This requirement means that all features have 3D attributes and would require adding elevation attributes to all features in NC Hydro. The 3DHP program is based on the 3DEP 1-meter digital elevation model (DEM), and Z-values must match the underlying 3DEP elevation data. HSSD data was processed using a custom 10-foot DEM, so even if elevation data is added to the line and polygon features, the data likely won't match the 3DEP data. It is unclear at this time whether the USGS will accept NC Hydro data. The HWG does not feel this should prevent North Carolina from trying to incorporate its data into the 3DHP, but rather, continue to communicate with the USGS and align as many specifications and attributes as possible to the 3DEP. If future opportunities exist for North Carolina to incorporate its data into the national dataset, the dataset should be meet as many specifications as possible.

In addition to matching the 3DEP DEM, Z values must also be just below (within the vertical accuracy) of the lidar elevation surface and maintain downstream monotonicity (each vertex elevation must be lower than the adjacent upstream elevation). Neither of these USGS specifications were noted by state and local stakeholders as important, so they were not included in these recommendations. However, if North Carolina plans to contribute to the 3DHP, it will need to make sure these specifications are met which could be considerable effort.

Z Enabled features was a specification that was not strongly needed by a majority of stakeholders. There were those that felt it was important, but stakeholders raised questions related to whether the Z value represented the actual stream channel bed elevation which changes frequently and is difficult to capture through Lidar. Stakeholders recognized that Z values could be useful in the future as they find more ways to use the data, but were not uniformly in need of Z values at present.



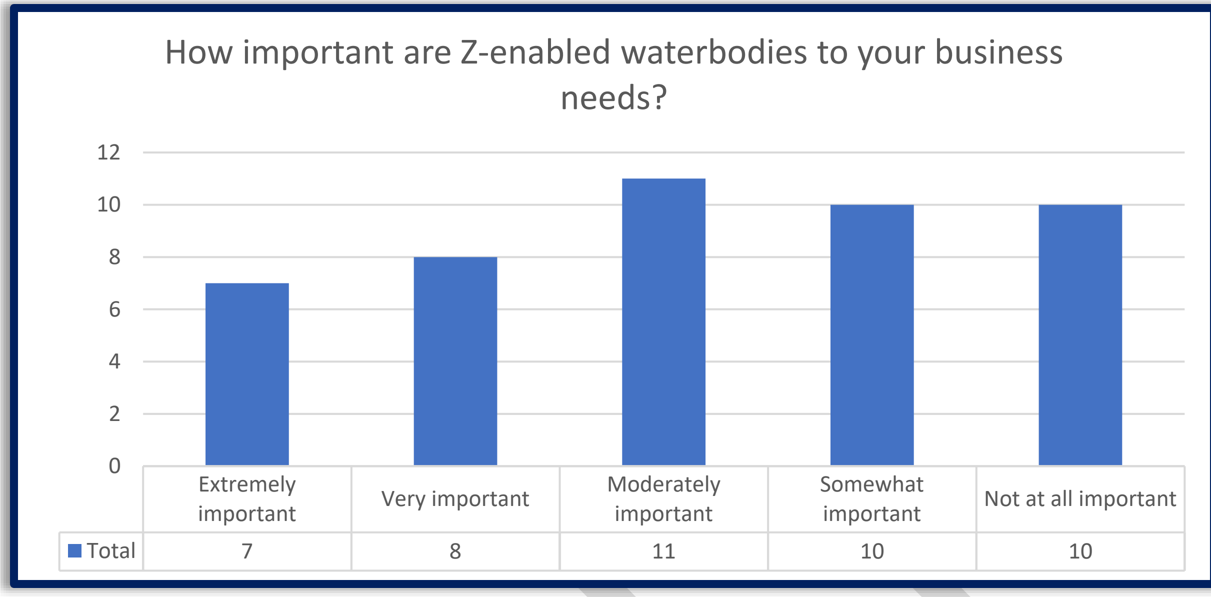


Figure 26. HWG Survey Results: Users were asked to rank the importance of Z values to their business needs for both lines and polygons.

Recommendation: Add Z values if possible. This feature is a lower priority than other gaps.

Water Boundary Dataset

Stream Connectivity

When HSSD data is created, each HUC is processed separately, so the outflow streamline from one HUC may not exactly match the point in the downstream HUC where the stream begins. Gaps or misaligned streams occur frequently. Connectivity in the network was important to stakeholders, and these gaps prevent tracing upstream and downstream. These connectivity issues will need to be updated, a time intensive process. Due to the need by many stakeholders for a connected network, this should be a high priority.

*Figure 27. **Left-** red lines delineate the boundary of a 10-Digit HUC where HSSD models are not connected. **Right**- Detail of boundary area showing missing stream centerline and disconnected tributaries.*

Recommendation: All flow lines must be connected at nodes, without gaps, crossed lines, or overshoots.

Watershed Boundaries

Watersheds are not part of ATLAS. The HWG concentrated heavily on outreach related to stream lines and waterbodies, and did not gather as much feedback about watershed boundaries outside of the HWG. It was generally accepted that watershed boundaries are important and that the difference in base data used to create the HSSD and the older NHD could produce minor differences in watershed boundaries. These differences are likely more noticeable in the coastal plain where small differences in elevation can greatly affect the direction of modeled water flow. Watersheds are a common analysis and summary feature level and should match the stream network. NC Hydro watershed boundaries will be attributed with the USGS HUC that intersects the majority of the feature. HWG members do not anticipate major differences between USGS and NC Hydro watershed features, so attribution with USGS HUC codes should not be a time intensive task. There are some differences between watershed names used in NC and the USGS, and these will also be in the attributes.

Recommendation: Create NC Hydro WBD to match the underlying HSSD DEM and stream network data. Attribute with USGS codes to allow potential integration into 3DHP.

Stewardship and Maintenance

Roles

HSSD data is created by DWR, and ATLAS is a NCDOT product. A long standing fiscal and partner relationship exists between DWR and NCDOT. A maintenance plan must be formalized, but the current relationship is expected to continue to improve hydrography data. Many of the gaps mentioned in this paper are un-funded and do not have a formal plan for implementation. NCDOT has expressed a willingness to consider future updates, but funding and staffing will be limiting factors. To fully implement NC Hydro, the GICC will need to make recommendations to the Governor and the General Assembly for additional funding, in keeping with the Council's advisory role on geospatial matters.

The NCDOT recognizes the value of NC Hydro upgrades and may incorporate elements developed specifically for the NC Hydro into the ATLAS Hydro versions 3 and later. While potentially outside of the direct needs of the ATLAS users, continued collaboration and the retention of upgrades could streamline the transition of future ATLAS Hydro datasets to NC Hydro datasets.

Update and Maintenance

The HSSD program plans to continue to update models as new base data becomes available. This new data will be incorporated into NC Hydro on a regular basis to be determined by the HWG and participating partners.

DWR will maintain the NC Hydro database and web services. NC DEQ is currently implementing an enterprise GIS that will store the data. Until that time, there are no plans to serve the data publicly due to the dataset size and resulting web service performance. DWR and DOT will be formalizing update roles and responsibilities prior to data release.

Stewardship

Most states have a formal stewardship agreement with the USGS for hydrography data maintenance. NC does not have an agreement. HWG members would prefer to see NC Hydro data incorporated into the 3DHP national dataset, so many of the recommendations in this document refer to 3DHP specifications in order to best align the data with the national dataset. However, the 3DHP is based on a 1-meter 3DEP DEM, and NC had already made significant investment in elevation derived hydrography based on a 10-foot DEM prior to the announcement of the 3DHP program. It is unclear whether NC data would be accepted into the national dataset, and even if it is, there is a strong likelihood that additional work would be required to bring the dataset to the necessary specifications. Therefore, the HWG has recommended an approach that puts completion of NC Hydro to NC user needs as a priority with future incorporation into the 3DHP as a goal if possible. The HWG fully intends to continue its frequent communication with the USGS to ensure that NC Hydro is as closely aligned with the 3DHP model as possible within our limitations. A formal stewardship agreement between DWR and USGS would be beneficial if the state finds that incorporation into the 3DHP is possible. This stewardship agreement would allow North Carolina to approve changes submitted through a federal markup tool and maintain consistency between the state and federal datasets.

Additional Considerations

State and Local Needs

State and local government users are primary stakeholders and heavily use hydrography data for a variety of tasks. The HWG discussed use cases during the course of most meetings, and stormwater connectivity was a common use case. The current NC Hydro specifications do not contain a dataset specific to stormwater, but the group felt it was important to continue to discuss the needs of these stakeholders and support the integration of stormwater data in the future.

Culverts are an important data source for properly routing stream features through topographically high areas. Culvert data exists from many sources and varies in accuracy. Accurate culvert datasets could improve the accuracy of the hydrographic network. Improving this fundamental data layer statewide would improve the overall accuracy of NC Hydro.

Federal Needs

The 3DHP has well documented specifications and USGS partners on the HWG keep the group updated on changes and updates to the program. Not all 3DHP specifications are covered in this document, and many other gaps exist that are not discussed here. HWG members concentrated on developing specifications specific to NC stakeholder needs, many of which overlap with the 3DHP. The state of North Carolina could pursue a funding partnership with the USGS through their new Data Collaboration Announcement (DCA) to produce 3DHP compliant data for NC. There are relatively few NC Hydro needs that are not included in 3DHP specifications. Base data elevation model and North Carolina's need for AU attributes and geometry as well as shorelines are the biggest differences. Given the investment already made in HSSD and ATLAS, the HWG did not recommend this course of action at this time. Lack of funding, and the need for a more immediate NC Hydro dataset were the two most important factors in this decision. However, HWG understand the importance of updating NC data at the national level and have considered 3DHP compatibility with each recommendation.

Gap Analysis Summary

The following table summarizes the current gaps between ATLAS Hydrography, NC Hydro and EDH. The left column lists the gaps described above, and the right two columns indicate whether the gap is necessary for NC Hydro or EDH. **ATLAS Hydrography Gaps**	**NC Hydro**	**EDH**
Polyline Issues		
Stream Segmentation		
Combine segments between confluences.	☒	☒
Reaches will be split where needed to represent breaks in DWR Assessment Units.	☒	☐
Smoothing		
Smooth rasterized lines for a cartographic appearance while maintaining accuracy within EDH specifications when possible.	☒	☒
Shorelines		
Develop both a shoreline feature in the polyline dataset (or a separate shoreline dataset)	☒	☐
Add polygon waterbody feature in the polygon dataset	☒	☒
Topology must be maintained between the two features	☒	☐
Waterbody Issues		
Waterbody size		
Add waterbodies that meet the minimum ¼ acre size to the dataset.	☒	☒
2D Rivers		
Add streams and rivers represented as polygons to match current EDH and Western NC Hydrography specifications.	☒	☒
Feature attributes and network connectivity		
Hanging Waterbodies		
Where preferential flow paths exist, connect hanging lake/ponds to the stream network with an attribution of modeled connector.	☒	☒
New waterbody must be mapped in between a hanging waterbody and the start of the network.		
Add waterbodies that meet the minimum ¼ acre size to the polygon dataset.	☒	☒
Add waterbody shorelines that meet the minimum ¼ acre size to the polyline/shoreline dataset.	☒	☐
Connect hanging lake/ponds to the stream network with an attribution of modeled connector.	☒	☒
Add artificial paths through the waterbody.	☒	☒
New waterbody is added upstream of most upstream feature in the network. This could be upstream of a pond or of the stream origin point.		
Add waterbodies that meet the minimum ¼ acre size to the polygon dataset.	☒	☒
Add waterbody shorelines that meet the minimum ¼ acre size to the polyline/shoreline dataset.	☒	☐
Connect hanging lake/ponds to the stream network with an attribution of modeled connector.	☒	☒

ATLAS Hydrography Gaps Continued	NC Hydro	EDH
Feature attributes and network connectivity		
New waterbody is added in line on an existing stream.		
Add waterbodies that meet the minimum ¼ acre size to the polygon dataset.	☒	☒
Add waterbody shorelines that meet the minimum ¼ acre size to the polyline/shoreline dataset.	☒	☐
Attribute stream segment as artificial path where it flows through the waterbody.	☒	☒
New waterbody is added that has no discernable overland connection to the network.		
Add waterbodies that meet the minimum ¼ acre size to the polygon dataset.	☒	☐
Add waterbody shorelines that meet the minimum ¼ acre size to the polyline/shoreline dataset.	☒	☐
A connector will not be added to the stream network unless a connection is confirmed through field or additional investigation.	☒	☐
Waterbody differentiation		
Split waterbody features to represent distinct rivers and lake features, and split complex lake features with multiple shoreline assessment units into distinct units.	☒	☐
Z Enabled Features		
Add Z values according to EDH READ rules	☐	☒
Water Boundary Dataset		
Stream connectivity		
Edit network to ensure stream network connectivity between 10-digit HUCS	☒	☒
Watershed Boundaries		
Create watershed boundaries to meet USGS WBD specifications	☒	☒
Attribute watershed boundaries and coordinate with USGS for attribution	☒	☒
Stewardship and Maintenance		
Roles		
Continue partnership between DWR and DOT.	☒	☐
Formalize roles and responsibilities.	☒	☐
Update and Maintenance		
Implement Enterprise GIS to serve data and formalize relationships with potential editors outside of DWR and DOT	☒	☐
Stewardship		
Maintain communication with USGS and look for opportunities to push NC Hydro to the national dataset.	☒	☐
NHD Specific Issues		
Data must match underlying 3DEP 1-meter DEM	☐	☒
Hydroflattened waterbodies	☐	☒
EDH attributes	☐	☒
Point feature class	☐	☒